THE CARRYING CAPACITY OF THE ICHETUCKNEE SPRINGS AND RIVER

BY

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CONTENTS

ACKNOWLEDGEMENTS. ii

LIST OF TABLES. vi

LIST OF FIGURES vii

LIST OF COLOR PLATES. x

ABSTRACT. xi

INTRODUCTION. 1
- Geology. 1
- Hydrology. 3
- Water Quality. 5
- Morphology of the Ichetucknee River. 5
- Vegetation 7
- Natural History. 7
- Cultural History 9
- History of Recreational Use. 10
- Profile of Park Users. 11
- The Carrying Capacity Concept. 13

OBJECTIVES. 19

METHODS 20
- Base Map 20
- Standing Crop. 21
- Plant Damage Survey. 21
- Plant Resistance 24
- Changes in Plant Cover 24
- Plant Recovery 24
- Response to Repeated Cutting 31
- Fauna Survey 31

RESULTS 34
- Base Map 34
- Types and Amounts of Recreational Use. 35
- Plant Damage Survey. 37
- Plant Resistance 51
- Changes in Plant Cover 51
- Experimental Plots 56
- Exclosures 66
- Blue Hole Cages. 75
- Response to Repeated Cutting 79
- Fauna Survey 81

CONTENTS
(Continued)

DISCUSSION 88
Impact of Recreation on the Plant Communities of the Headsprings Reach. 88
Impact of Recreation on the Plant Communities of the Rice Marsh and Floodplain Reach. 112
Impact of Recreation on the Animals of the River . . . . 124 √
The Carrying Capacity for Recreation. 127

LITERATURE CITED 139

APPENDICES

A. METHODS OF INDIRECT MEASUREMENT 142

A-1. PERCENTAGE DRY WEIGHT OF NETTED PLANTS, PLANT DAMAGE SURVEY, SUMMER, 1978. 142

A-2. RELATIONSHIP OF CLUMP BIOMASS AND LENGTH OF LONGEST LEAF, *Sagittaria kurziana* 144

A-3. RELATIONSHIP OF LEAF WEIGHT AND LEAF LENGTH, *Sagittaria kurziana* 145

A-4. INDIRECT AND DIRECT MEASUREMENT OF PLANT BIOMASS IN EXPERIMENTAL PLOTS. 146

B. AMOUNTS OF HOURLY USE AND DAMAGE, BY SPECIES, PLANT DAMAGE SURVEY, SUMMER, 1978. 147

C. BIOMASS OF AQUATIC PLANTS OF THE ICHETUCKNEE RIVER 154

D. STANDING CROP OF AQUATIC PLANTS IN THREE REACHES OF THE ICHETUCKNEE RIVER. . . . . 156 -

E. PLANT COMMUNITIES OF THE ICHETUCKNEE RIVER. . . 157 -

BIOGRAPHICAL SKETCH. 176

LIST OF TABLES

Table

1. Water quality of the Ichetucknee Springs. 6

2. Common species of the plant communities of the Ichetucknee Springs State Park 8

3. Regrowth of aquatic plants following cutting or uprooting. 57

4. Plant biomass and the number and weight of invertebrates sampled in three areas subject to varying degrees of recreational disturbance 82

5. Types and numbers of fish in disturbed (First Dock area) and undisturbed (Headsprings Exclosure) sections of the Headsprings Reach 85

6. Recommended carrying capacities 128

LIST OF FIGURES

Figure

1. Map of Ichetucknee Springs State Park. 2

2. Annual park attendance, 1973-74 to 1977-78 . . . 12

3. Location of netting stations and experimental plots 23

4. Location of fenced exclosures, map-remap sections, and fauna survey sites 25

5. Location of cages in the Blue Hole 29

6. Types and amounts of recreational use, January-August, 1978 36

7. Winter plant damage related to total number of users and to number of divers 38

8. Damage, by species, related to number of divers, Winter, 1977-78. 40

9. Percent total damage and percent of total standing crop of species netted in Winter, 1977-78. 43

10. Amounts of daily plant damage and daily use in three reaches, Summer, 1978 45

11. Amounts of hourly plant damage and use in three reaches, Summer, 1978. 47

12. Number of users and fractional loss of standing crop, for three reaches, Summer, 1978 48

13. Percent total damage and percent total standing crop for plant species in three reaches, Summer, 1978. 50

LIST OF FIGURES
(Continued)

Figure

14. Resistance to tearing and uprooting. 52

15. Seasonal changes in plant cover in three sections of the Headsprings Run. 53

16. Standing crop and recovery of *Sagittaria* leaves following cutting 60

17. Standing crop and clump recovery of *Sagittaria* following uprooting 60

18. Number of *Sagittaria* clumps counted in quadrats following uprooting, and standing crop (no. of clumps) in undisturbed quadrats sampled in February and June, 1978. 61

19. Standing crop and regrowth of *Myriophyllum* following cutting. 65

20. Change in plant cover, Site A, Headsprings Exclosure, 6-12-78 to 8-24-78. 67

21. Change in channel profile, Site B, Headsprings Exclosure, 8-3-78 to 10-12-78. 71

22. Change in plant cover, Second Dock Exclosure, 7-25-78 to 10-26-78 72

23. Growth of *Zizania* and *Chara*, Second Dock Exclosure 74

24. Characteristics of *Sagittaria* leaves sampled both inside and outside of Jug Cage. 76

25. *Sagittaria* colonization and characteristics of leaves sampled inside and outside of the Run Cage 78

26. *Sagittaria* leaf recovery in plots subjected to repeated cutting. 80

27. Amounts of daily use and plant damage, Headsprings Reach, Summer, 1978. 90

LIST OF FIGURES
(Continued)

Figure

28. Amounts of hourly use and plant damage for five survey days, Headsprings Reach, Summer, 1978. 91

29. Species damage in the Headsprings Reach, April to August, 1978 98

30. Amounts of *Sagittaria* torn and uprooted over varying levels of diving activity and amounts recovered in plots experimentally subjected to tearing and uprooting 103

31. Size distribution of *Sagittaria* clumps uprooted by divers compared to the size distribution of clumps sampled from the Devil's Eye Exclosure, which receives no use . . 104

32. Damage Index for three reaches of the Ichetucknee River. 115

33. Damage Index related to physical characteristics of the river and behavioral characteristics of use. 117

34. Fractional loss and fractional recovery rate of *Sagittaria*, *Myriophyllum*, and *Vallisneria*. 121

LIST OF COLOR PLATES

Plate

1. Headsprings Exclosure, July and November. 70
2. Tuber impact on the Blue Hole 95
3. *Sagittaria* bed, April and August, 1978. 97
4. Channel erosion in the Second Dock Area 114

Abstract of Thesis Presented to the Graduate Council
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CARRYING CAPACITY OF THE ICHETUCKNEE SPRINGS AND RIVER

By

Charles DuToit

June 1979

Chairman: John Ewel
Major Department: Botany

A study was conducted in 1977-78 to determine the types and amounts of recreational use that the communities of Ichetucknee Springs and River can sustain without causing irreversible damage. I measured the kinds and amounts of damage which result from swimming, canoeing, diving and tubing, and monitored the recovery of aquatic communities. A carrying capacity, defined as the rate of use at which damage is equal to the natural ability of each plant community to recover, was recommended for each type of use.

Tubing is, numerically, the most important form of recreation at the Ichetucknee Springs; 3000 people per day (the present limit) regularly float down the River on tubes on summer weekends, and weekday use generally exceeds 1000. The reach between the Headsprings and the Blue Hole sustains the greatest impact, both in terms of channel and bank erosion and in terms of percentage loss of vegetation. Trampled plant beds support less shrimp and crayfish than healthy beds, and disturbed areas contain fewer types and numbers of fish than undisturbed areas. The middle and lower reaches lose proportionally less vegetation and, with some local exceptions, are not eroded by recre-

ational use. Channel width and depth do not directly account for these differences, but changes in the behavior of users, who become more passive as they progress downstream, may be the most important factor. A limit of 100 tubers per hour is recommended.

In winter, diving groups (2 to > 50 individuals) visit the Park to snorkel in the River and dive in the Blue Hole. Plant damage increases exponentially as diving activity in the Blue Hole increases. Crowding in the pool, poor group control, and trampling along the edge of the Blue Hole run account for this accelerated impact. The Sagittaria community, which comprises 75% of the total cover in the Blue Hole, sustains the greatest damage. Recolonization of disturbed areas by Sagittaria is very slow in winter; the amount of regrowth in a day is about equal to the amount of damage caused by 50 divers in four hours. On busy days, when as many as 100 divers visit the Park, damage may exceed recovery by an order of magnitude. To save the natural ecosystems in Blue Hole, a limit of 12 divers per hour should be enforced.

Swimming and canoeing are minor components of recreational use at the Park. Although swimming, and the trampling that accompanies it, result in loss of cover and bottom erosion, this activity is largely confined to the Blue Hole and Headsprings pool. Canoeing appears to have little impact on submerged plant communities; paddles cause little stem and leaf breakage and practically no uprooting. If the amount of swimming and canoeing does not increase substantially, no limit need be placed on these activities.

John Ewel

Chairman

INTRODUCTION

The Ichetucknee Springs State Park, located in north-central Florida, is one of the State's most unique resources: a clear, spring-fed river which winds through hammock, open marsh, and floodplain forest. The Park, comprising an area of 910 hectares (2,250 acres), straddles southeast Columbia County and southwest Suwanee County; the Ichetucknee River forms a natural boundary between the two counties. The land for the Park was purchased in 1970 by the State of Florida from a British mining firm, the Loncala Phosphate Company.

Geology

The Ichetucknee Springs State Park (Fig. 1) lies in the Coastal Lowlands, a physiographic region defined by surface elevations less than 30 meters (100 feet) above mean sea level and locally characterized by karst topography, evident in the numerous springs, sinkholes, and limestone outcrops in the area. A geologic section in the area of the Park would show a surface mantle of sand and clay overlying a thick bed of limestone, about 915 meters (3000 feet) deep, which rests unconformably over Paleozoic basement rock. The upper layers of limestone sediment, of late Eocene age, are collectively called the Ocala group, which, being highly

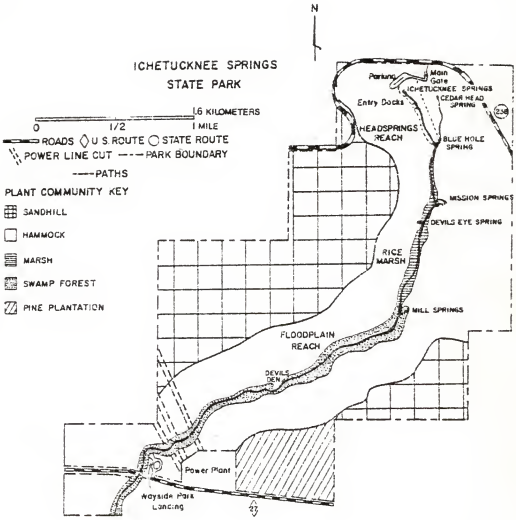


Figure 1. Map of Ichetucknee Springs State Park. Map was prepared from aerial photographs (U.S.D.A., 3-31-74) and U.S.G.S. topographic quadrangle (Hildreth, FL, 1968).

permeable, forms the dominant water-bearing formation in north-central Florida. This aquifer is overlain by Miocene deposits, the Hawthorn and Alachua formations, which consist of clay, phosphatic sand, and discontinuous beds of limestone. A surface deposit, predominantly consisting of unconsolidated sand, was laid down over Miocene sediment during the interglacial periods of the Pleistocene when sea level ranged 7.5-30 meters (25-100 feet) higher than at present (Meyer 1962).

The major geologic features of the Coastal Lowlands can be observed at the Ichetucknee Springs State Park. Ocala limestone outcrops in bluffs along the river; Miocene deposits containing phosphatic ore are exposed in mining pits in the hammock; and Pleistocene sands are everywhere evident in the Sandhill community at higher Park elevations.

Hydrology

The Ichetucknee River lies in an ancient basin, the Ichetucknee Trace, which is roughly defined by the 50 foot contour level on U.S.G.S. topographic maps of south Columbia County. Rose Creek and Clay Hole Creek, in the vicinity of Lake City, form the headwaters of the basin. Surface flow from these creeks is intercepted by sinkholes near the town of Columbia which is located about 16 kilometers (10 miles) southwest of Lake City. Here, the captured surface flow mingles with groundwater and eventually emerges at the Ichetucknee Springs.

Geologists believe that the Ichetucknee Trace developed along fracture lines associated with the uplift of the Peninsular and/or Ocala arch (Meyer 1962).

Ocala limestone outcrops, or lies at or just below the surface, in the Ichetucknee Trace. Ground water is discharged in areas such as the Ichetucknee Springs where the piezometric surface, or hydraulic head of the aquifer, is higher than the topographic surface. Geologists recognize two sources of discharge in the Ichetucknee Springs: 1. ground water from regions of higher artesian head in northern Columbia County and surrounding areas, and 2. local rainfall which enters the aquifer through sinkholes, limestone outcrops, or permeable sand deposits (Meyer 1962).

The discharge of the major springs of the Park is shown in Figure 1. The average discharge of the Ichetucknee River, measured at the Highway 27 Bridge, is 10.1 m^3/sec. (358 c.f.s.), which ranks sixth in magnitude among Florida springs. The minimum discharge recorded over a period extending from 1917 to 1972 was 6.8 m^3/sec. (241 c.f.s.), which is 33% below average discharge. The maximum discharge during this period was 16.4 m^3/sec. (578 c.f.s.), 61% above the average flow (Rosenau and Faulkner 1974).

In Columbia County, groundwater rise generally lags five months behind the period of maximum rainfall, which occurs during the summer months (Meyer 1962). Small discharge increases, of short duration, result from local recharge by rainstorms.

Water Quality

The water temperature of the Ichetucknee River remains, year round, about 22°C, which is approximately equal to the mean annual air temperature of the region. Table 1 shows the chemical characteristics of the water from a 1946 analysis (Ferguson et al. 1947). Inspection of this figure shows that the river water is alkaline (pH 7.7) and that calcium and bicarbonate are the two most important dissolved mineral ions. Color was measured to be 0, indicative of the remarkable clarity of the spring water.

Morphology of the Ichetucknee River

Three reaches can be distinguished in the Ichetucknee River. The Headsprings, or Ichetucknee Springs, with a discharge of 1.3 m^3/sec. (45 c.f.s.), is the source of the "Headsprings Run,"[1] defined as that portion of the river between the Headsprings and the Blue Hole (Fig. 1). This reach is relatively narrow and shallow, with an average width of about 10 meters and depth of 1 meter, and is partially shaded by hammock vegetation growing on the banks.

The section of the river between the Blue Hole and Mill Springs, about 1.6 kilometers (1 mile) in length, is called the "Rice Marsh." Discharge from the Jug Springs at Blue Hole (about 2.4 m^3/sec.), Mission Springs (1.4 m^3/sec.), and Devil's Eye Spring considerably strengthens the river

1 The "Headsprings Reach," a term used throughout this report, includes the "Headsprings Run" and the Headsprings and Blue Hole.

Table 1. Water quality of the Ichetucknee Springs. Data are from Ferguson et al. (1947).

CHEMICAL ANALYSIS May 17, 1946	
	Parts Per Million
Silica (SiO_2)	9.1
Iron (Fe)	.03
Calcium (ca)	58
Magnesium (Mg)	6.6
Sodium (Na)	3.1
Potassium (K)	0.3
Bicarbonate (HCO_3)	200
Sulfate (SO_4)	8.4
Chloride (Cl)	3.6
Fluoride (F)	.1
Nitrate (NO_3)	1.0
Dissolved Solids[a]	188
Total Hardness as $CaCO_3$	172
Carbon Dioxide (CO_2)	6
Other Measurements	
Color	0[b]
pH	7.7
Specific Conductance ($K \times 10^5$ at 25°C)	32.9

a. In a 1972-73 analysis by U.S. Geological Survey, dissolved solids measured 170 mg/l (Rosenau and Faulkner 1974).

b. Color units are not specified by Ferguson et al. Their measurement is based on a graduated scale of colored disks and is presented here to indicate the relative clarity of the water. Some swamp water measures 200 or more on the colored disk scale.

flow in this reach. A short distance below Blue Hole the river widens to about 60 meters with an extensive marsh of wild rice, Zizania aquatica, bordering an open channel, which is 15 to 20 meters wide and about 2 to 3 meters deep.

The "Floodplain Reach" is that portion of the river between Mill Springs and the point of discharge of the Ichetucknee River into the Santa Fe River. In this reach the river is 15 to 20 meters wide and 1-2 meters deep and is bordered by floodplain forest and limestone bluffs.

Vegetation

Three life forms of vascular plants are common in the open channel and floodplain of the Ichetucknee River: submerged macrophytes in the open channel, emergent macrophytes in the marsh, and arboreal vegetation in the floodplain swamp. Table 2 shows the common species of the river and the upland communities. Sandhill vegetation occupies about 273 hectares (675 acres), or 30% of the Park area, and grows on Pleistocene sand deposits at higher elevations of the Park. Hammock trees grow in the rich calcareous soil of river banks and cover about 590 hectares (1460 acres), or 65% of the total area. River plants and floodplain forest occupy about 5% of the Park.

Natural History

The Indian word "Ichetucknee" means "beaver pond." Ironically, beaver are rarely observed in the Park, and in fact, had not been seen for decades until the fall of 1977

Table 2. Common species of the plant communities of the Ichetucknee Springs State Park.

Sandhill	
Pinus palustris	longleaf pine
Quercus laevis	turkey oak
Quercus margaretta	sand-post oak
Aristida stricta	wire grass
Mesic Hammock	
Quercus virginiana	live oak
Quercus hemisphaerica	laurel oak
Magnolia grandiflora	southern magnolia
Carya glabra	pignut hickory
Persea borbonia	redbay
Ilex opaca	american holly
Acer barbatum	florida maple
Swamp Forest	
Taxodium distichum	bald-cypress
Nyssa biflora	blackgum
Nyssa aquatica	water tupelo
Acer rubrum	red maple
Aquatic	
Sagittaria kurziana	eel-grass
Vallisneria americana	tapegrass
Zizania aquatica	wild rice
Chara sp.	musk-grass
Myriophyllum heterophyllum	foxtail
Ceratophyllum demersum	coontail
Ludwigia repens	red ludwigia
Nasturtium officinale	watercress
Najas guadalupensis	southern naiad
Cicuta maculata	water-hemlock
Pistia stratoites	water-lettuce
Fontinalis sp.	water-moss

when one was observed in the Headsprings Run during the early days of our research. The long absence and recent return of the beaver is only one of the interesting features of the natural history of the Ichetucknee Springs. A monkey has been reported; wild turkey, bobcat, and deer are commonly seen in the woodlands, and a great variety of birds and fish, as well as otter, inhabit the marshes and river.

Less conspicuous features of the Springs are Eocene fossils of mollusks, echinoderms, and foraminifera that are embedded in submerged limestone banks and emergent bluffs. The bones of terrestrial vertebrates of the Pleistocene have been found in alluvial deposits along the Ichetucknee River. The remains of an extinct bison were unearthed during the construction of a canoe ramp in 1973, and the bones of mammoths, mastodons, and a Pleistocene lion, *Felix atrox*, have been recovered at the Park.

Cultural History

Anthropologists believe that the Utina Indians, a tribe of the Western Timucuans, lived in the area of the Park in prehistoric times. In 1950, John Goggin of the Florida State Museum, excavating a refuse mound, unearthed evidence of a Spanish-Indian contact on the banks of Ichetucknee River. The recovery of both European and Indian artifacts, including a lead cross and ceramic vessels, suggested that a Spanish church formerly occupied this site, now known as Mission Springs (Deagan 1972). The remains of a grist mill

and earthworks at Mill Springs indicates more recent occupation of the riverbanks.

History of Recreational Use

The type and amounts of use of the Ichetucknee River and woodland has changed considerably from pre-Park days to the present. Ferguson et al., in a 1947 publication, The Springs of Florida, relate that the Headsprings was used for watering stock, as well as for swimming and picnicking. Fishermen and hunters frequented the river and uplands and camped on the wooded river banks. The river was additionally subject to unregulated use by local residents and college students, whose beer cans were conspicuously evident prior to a cleanup by the State. Under the administration of the Department of Natural Resources, the Park has instituted a number of regulations designed to limit environmental abuse, and has developed facilities to increase access and visitor comfort. A user now pays a 25¢ admission charge; parking for cars and buses is provided at the Headsprings area, and trails and docks provide easy access to the river. Camping is prohibited, and visitors are not allowed to carry food or beverages on the Ichetucknee River. A shuttle bus, operating from the Wayside Park on Highway 27, transports users back to the Headsprings area at the end of a run.

The Ichetucknee Springs under State ownership has become an extremely popular resource; its facilities, cleanliness, and recreational opportunities appeal to family

groups, community organizations, tourists, dive clubs, and the general public. As shown in Figure 2, the amount of Park use has increased considerably during this decade. The amount of annual use remained fairly constant until 1976, when there was a 35% increase (about 50,000 users) over the previous year's attendance. On July 4, 1977, nearly 5000 tickets were sold at the main gate. This was the largest amount of daily use ever recorded.

Profile of Park Users

In 1974 and 1975 a survey was conducted by the Florida Department of Natural Resources at the Ichetucknee Springs State Park to investigate the impact of crowding on a user's enjoyment of the experience. In addition to providing information on its primary objective, the survey furnished a sociological sketch of Park users.

Male visitors outnumber female visitors by a factor of two or more. Approximately 45% of the Park users are between the ages of 19 and 26; 10% are under 18, and about 25% between 26 and 35. The city of Gainesville, which has grown rapidly during this decade, is the largest single source of users (35% of total), followed by Jacksonville (about 20%), and the Fort White area (about 10%). An interesting survey statistic shows that, on the average, there are nearly nine individuals per tubing party. This fact is likely accounted for by the large family groups, college fraternities, and community organizations which regularly visit the Park.

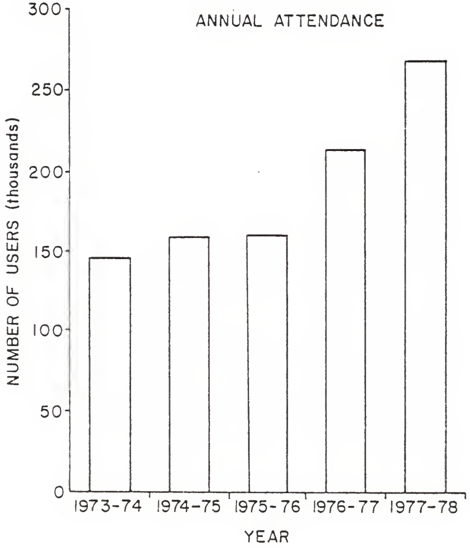


Figure 2. Annual park attendance, 1973-74 to 1977-78. Data are from annual attendance records which are based on monthly use totals from July through the following June.

The Carrying Capacity Concept

The signs of environmental deterioration that have accompanied increased use of the Park in recent years have prompted the Department of Natural Resources to impose a limit of 3000 users per day, as well as to sponsor research on the "carrying capacity" of the Ichetucknee Springs and River. The concept of a recreational carrying capacity has become increasingly popular with resource managers; however, it is not always clearly defined, and has been difficult to apply. Lime and Stanky (1971, p. 175), in a review of the development of the concept, provide a good definition:

> The recreational carrying capacity is the character of use that can be supported over a specified time by an area developed at a certain level without causing excessive damage to either the physical environment or the experience of the visitor.

In their definition, the authors emphasize the need for a multi-dimensional concept which includes three basic considerations: 1. user satisfaction, 2. environmental impact, and 3. the objectives of resource managers. The theoretical sources and applications of research in each of these three areas is summarized in the following discussion.

User Satisfaction

The most comprehensive study to date on user satisfaction is the nation-wide survey conducted by the Outdoor Recreation Resources Review Commission (ORRRC 1962) on the preferences and perceptions of users of State and National Parks. A number of other studies on visitor attitudes have

been conducted on a regional or local scale, such as the study by Lucas (1963) on the perception of "wilderness" by different types of users of the Boundary Water Canoe Area in northeast Minnesota, and locally, the survey conducted at the Ichetucknee Springs State Park in 1974-75. Briefly summarized, the results from these surveys demonstrate that Park users vary greatly in their recreational preferences, in their perception of environmental quality, and in their tolerance to interaction with other recreationists.

The recreational carrying capacity, from the viewpoint of user satisfaction, has been defined as "the maximum number of use-units (people, vehicles, etc.) that can utilize the available recreational space at one time for some activity while providing a 'satisfactory' experience for the user" (Lime and Stanky 1971, p. 174). The most popular application of this definition is the "space standard," a concept developed by the U.S. Forest Service which defines the amount of topographic space that a wilderness user needs in order to have a satisfactory day of recreation. The "space standard" for wilderness areas of National Forests is 3 acres per person per day (Douglas 1975).

The assumptions implicit in the concept of a "space standard" are similar to those inherent in the theory of the carrying capacity of natural populations. According to this theory, introduced by Verhulst in the 18th century, and mathematically formalized by Lotka, there is a limit

to the growth of natural populations due to density dependent interactions and shortages of available resources (Krebs 1972). The concept of a carrying capacity for user satisfaction is analogous to the concept of a growth limit on natural populations in the sense that a "space standard" ideally defines a level of use that an area can sustain above which density-dependent interactions (user-user contact) or environmental deterioration (recreational consumption of the resource) strongly detract from the enjoyment of the recreational experience. Although a "space standard" based on user satisfaction is a useful concept, it has a fundamental weakness. Lime and Stanky comment: "space standards based on user satisfaction have generally failed to incorporate the level of use the physical environment can tolerate over a given time before serious damage results" (Lime and Stanky 1971, p. 175).

Recreational Impact on the Resource

The majority of research on impact of recreational use on natural ecosystems has been concerned with the effect of hikers, campers, and picnickers on the vegetation and soils of State and National Parks. Investigations of recreational impact on lakes and rivers have been primarily limited to studies on the environmental effect of outboard motor discharge and watershed pollution (Stanky and Lime 1973). Basically, two approaches are used in research on recreational impact. One approach involves monitoring use levels and

measuring environmental damage in actual recreational situations. The other measures environmental damage under controlled levels of simulated impact, such as Wagar's (1964) use of a tamp to simulate trampling on foot paths. Recreational studies may be short term, such as Burden and Randerson's (1972) study on the effect of seven days of recreational use on a newly developed trail, or long term, as exemplified by Lapage's (1967) three-year study on plant cover changes at a New Hampshire campground. Historical investigations, such as Gibbens and Heady's (1964) work at Yosemite, use time-series photographs, naturalist writings, survey reports, and interviews to determine environmental change over extended periods of time.

The results of recreational impact studies have been used by the U.S. Forest Service to formulate a Ground Cover Index, which equates ground cover at a campsite with: 1. the amount of recreational use in the area, and 2. site characteristics, such as slope and depth of B horizon.

A problem with recreational impact studies is the element of uncertainty about the level of damage that a resource can tolerate without causing irreversible deterioration of a site. The consideration of this problem in other fields of ecology has led to the development of such concepts as ecosystem stability, resistance, and resilience (Bishop et al. 1974). Simply stated, these concepts are concerned with: 1. the ability of an ecosystem to resist

perturbation, 2. the rate and direction of recovery following disturbance (resilience), and 3. the threshold limit, or carrying capacity, beyond which the system is unable to return to its original condition.

Concepts of this nature underlie a great deal of carrying capacity research and are implicitly acknowledged, if not openly recognized, in many resource management decisions. Wagar (1964), in his tamp experiments, found that the "resistance" of terrestrial vegetation to trampling was partially a function of life form; grasses and woody vines are generally less vulnerable to trampling than dicotyledonous herbs. Resource managers commonly use a variety of techniques, such as paving heavily-used walkways and fertilizing and irrigating, to increase the "resistance" of a site (Lime and Stanky 1971). In England, Schoefield (1967) determined the "carrying capacity" of a dune walk to be 7500 users per season. Increasing the amount of use beyond this threshold limit resulted in soil exposure and dune erosion. Schoefield also considered the "resilience" of this dune system when he estimated that an eroded footpath would recover in four years if protected from further use.

Objectives for the Management of Recreational Resources

The management objectives for a recreational area should be ideally based on 1. user demands and preferences, 2. park philosophy, and 3. the durability of the resource. The park manager's problem of balancing recreation with

preservation is similar to that of fisheries or agricultural enterprises where overexploitation may deplete the resource. The concept of "optimum sustained yield" as a management objective for the fisheries and agricultural industries may be just as applicable to the management of recreational areas. The "sustained yield" concept is implicit in the following statement by the Outdoor Recreation Resources Review Commission (1962, p. 1) on the goal of maintaining "site quality" in recreational areas.

> site quality. . .the extent to which an area provides its intended amounts and kinds of recreation opportunities while being maintained in a long term productive condition.

OBJECTIVES

The objective of this research was to determine the amount of environmental change that results from varying types and amounts of recreational use. Information of this nature should greatly aid Park management in defining a carrying capacity that is consistent with their objectives of preserving the resource and meeting the public demand for recreation. To fulfill the stated goal of this research, answers to the following questions are provided.

1. What is the relationship of plant damage to:
   --the number of users?
   --the type of use?
   --the distribution of use, both daily and seasonally?
2. What areas of the spring system and river, and which plant communities, are most disturbed by recreational use?
3. What is the rate and kind of vegetation recovery following disturbance?
4. What impact does recreational use have on the animals of the springs and river?
5. Is the damage to plant and animal communities reversible or irreversible?

METHODS

Base Map

The Ichetucknee River was mapped to determine the distribution of aquatic macrophytes. The method of mapping varied over the river, depending on the width and depth of the major reaches. The Headsprings Run, about 500 meters in length, was mapped in 10-meter sections using two fiberglass meter tapes and a meterstick. One meter tape was stretched across the run, perpendicular to the main channel. A second tape was stretched parallel to the first, 10 meters downstream. The plant beds in each section were mapped by a wading observer who used the tapes to chart bed position and the meterstick to measure the dimensions of the bed. Depth was also measured in each section and the type of bottom sediment noted. The Blue Hole pool and run were mapped in a similar fashion, except the tapes were 5 rather than 10 meters apart.

The portion of the river extending from the Blue Hole outlet to the Wayside Park Landing was mapped using a boat, as the channel was too deep to wade. A 20-meter anchor rope, marked at 5-meter intervals, served as a position reference by which an underwater observer charted the major plant beds. An assistant working from the boat took depth

soundings, measured river width with extension poles, and recorded the compass direction of the main channel in each 20-meter section.

Standing Crop

Samples of each of the major plant species were clipped or uprooted from quadrats of varying sizes. The samples were returned to the lab, oven dried (three days at 70°C), and weighed. The standing crop for each species was estimated by multiplying its sample weight/m^2 by its cover value (m^2), which was measured by planimetry of the base map.

Plant Damage Survey

The one-way flow of a river provides a researcher with an opportunity to directly measure the impact of trampling on aquatic vegetation. The relationship of plant damage to the amount of use can be estimated by counting users and collecting river drift simultaneously. This method was used throughout the study to measure the amount of damage to river plants over varying types and levels of recreational use.

Winter Survey

The impact of winter recreation was measured by sampling plant damage both on busy weekends and quiet winter weekdays over a period extending from December, 1977, to March, 1978. On sampling days, the researcher and his assistant collected

drift for a four-hour period from a point in the river located just below the Blue Hole outlet (Station 1, Fig. 3). Handnets were used to retrieve plant clumps and fragments, and recreationists entering Blue Hole or passing the collection station were counted and categorized according to type of use (scuba diver, snorkler, canoer, tuber, or swimmer). The netted material was returned to the lab, sorted according to species and type of damage (torn or uprooted), oven dried (three days at 70°C), and weighed.

Summer Survey

During the summer (April through August), when recreationists range over the entire springs system and river, plant damage was sampled one day each month from three different stations situated at the downstream end of each major reach. At Station 1, located just below Blue Hole Run (same station used in winter survey), plant material was netted by two wading assistants, while a third counted and categorized users. At Stations 2 and 3, located at Mill Springs and just below Wayside Park Landing respectively, drift was netted from either canoe or raft, as the depth of the channel prohibited wading. To assess the impact of rate of use (number of users per unit time), plant material was netted and the number of users recorded on an hourly basis throughout a sampling day.

At the end of a survey day, all the collected plant material was returned to the lab, and, as was done in the

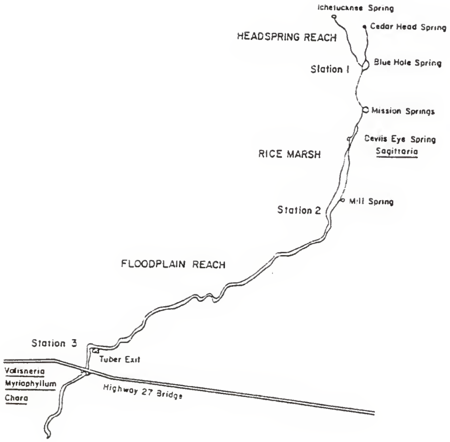


Figure 3. Location of netting stations and experimental plots. The three netting stations are identified by number, the experimental plots by genus name.

winter survey, sorted according to species and type of damage. As the available drying ovens could not accommodate the large volume of vegetation, the sorted plants were spread on screens and drained for an hour before taking a fresh weight. Several small samples (a handful) of each species were oven dried (three days at 70°C) to determine a dry weight equivalent for the fresh weight measurements.

Plant Resistance

A simple experiment was devised to test the ability of a species to resist tearing or uprooting. One end of a nylon string was tied to a plant stem just above the soil surface. The other end was secured to a spring aligned with a meterstick. Resistance was measured as the maximum amount of spring stretch (in cm) at the point of tearing or uprooting.

Changes in Plant Cover

To determine seasonal changes in plant cover, three sections of the Headsprings Run (Fig. 4) were mapped in November-December, 1977, remapped in April, 1978, and mapped again in August, 1978. The method was the same as was used in preparing the base map of the Headsprings Run: tapes, 10 meters apart, were stretched across the run, and plant bed positions and dimensions charted on graph paper.

Plant Recovery

Several methods were used to assess the rate of vegetation recovery following disturbance. One method involved

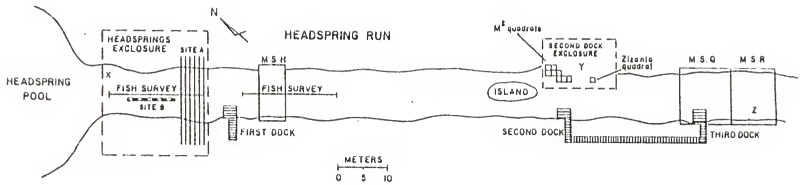


Figure 4. Location of fenced exclosures, map-remap sections, and fauna survey sites. The exclosures are indicated by dashed lines (---), and the map-remap areas by solid lines (——), with M.S. H, M.S. Q, and M.S. R identifying the specific map sections. The fish survey sites are indicated by lines with terminal bars (|——|), and the invertebrate survey sites by the letters X, Y, and Z. Also included are the location of the m^2 quadrats in the Second Dock Exclosure, and the areas in the Headsprings Exclosure (sites A and B) where channel closure was measured.

monitoring the recovery of sample plots which were experimentally subjected to injuries similar to the kinds of damage (tearing, uprooting) caused by recreational use. A second method involved the measurement of plant regrowth in trampled beds, which were protected from further disturbance by fenced exclosures. A third way was to monitor plant growth in cages situated in areas of heavy recreational use.

Experimental Plots

Basically, two types of treatment were used to simulate the types of injury which result from trampling: 1. Plant stems and leaves lying in the water column above a quadrat were cut back to the substrate level. 2. All rooted plants lying within the boundaries of a staked quadrat were pulled from the substrate. Appendix A-4 describes the methods used to measure the regrowth of a number of plant species used in this experiment.

Exclosures

The Park staff constructed two fenced exclosures in the Headsprings Run (Fig. 4). One exclosure, situated between the Headsprings pool outlet and the First Dock, protected an area that had been previously subjected to a moderate degree of trampling. A second exclosure was erected on the eastern side of the run opposite the Second Dock. Prior to fencing, the riverbed in this area had been extensively trampled by wading tubers.

Headsprings Exclosure. Vegetation recovery was monitored in two sections of the reach protected by the Headsprings Exclosure. At Site A (Fig. 4), a 5-meter-long section of the run lying immediately above the downstream fence, the dominant plant beds were mapped on June 12, 1978, and on August 24, 1978. An open grid was laid out to provide a fixed reference for measurement of the beds. Nylon strings, marked at meter intervals, were stretched above the channel between pipes which were aligned in opposite pairs, one meter apart, along the banks. The position of plant beds was measured by running a plumb bob perpendicularly from the marked strings down to the submerged beds.

A second section of the Exclosure, Site B (Fig. 4) was used to measure channel closure. A meter tape was stretched underwater from a pipe sunk in the channel floor to a second pipe sunk 10 meters downstream. Channel width was measured with a marked rod, which was held perpendicularly to the tape at each meter interval over this section. Measurements were taken on August 3, 1978, and October 12, 1978.

Second Dock Exclosure. A heavily-trampled river bed, protected from further disturbance by the Second Dock Exclosure, was sectioned into eight 1 m^2 units to facilitate detailed measurement of plant cover changes (Fig. 4). In each unit, stakes were fitted tightly into the corners of a 1 m^2 quadrat and sunk permanently in the underlying substrate. Cover was measured on July 25, September 6, and

October 26, 1978, by positioning the quadrat, which was subdivided into one hundred 0.01 m^2 units, over the stakes and mapping the areas occupied by the constituent species in each quadrat.

In a separate section of the exclosure, the same method was used to monitor the recovery of *Zizania* plants in a 1 m^2 quadrat (Fig. 4). In addition to mapping cover, plant size was noted by measuring the length of the three longest leaves of each *Zizania* plant in the quadrat.

Cages

Two cages were installed in the Blue Hole (Fig. 5). One cage, secured to the bottom in late May, was situated in the channel 10 meters downstream from the Jug, the spring water outlet in the Blue Hole. A second cage, installed in June, was situated about 5 meters from the Jug, on the south side of the Blue Hole pool. Both cages were made of hurricane fencing and had the same dimensions: 1 x 1 x 1.75 meters.

Run Cage. The cage in the channel, designated Run Cage, enclosed an area that was vegetated in part by *Sagittaria*, the remainder being open sand. On May 29, shortly after installation, the channel-ward edge of the *Sagittaria* bed was marked with stakes to provide a reference for future measurement of vegetation outgrowth. Substrate level was measured on the stakes, which had been marked off at centimeter intervals.

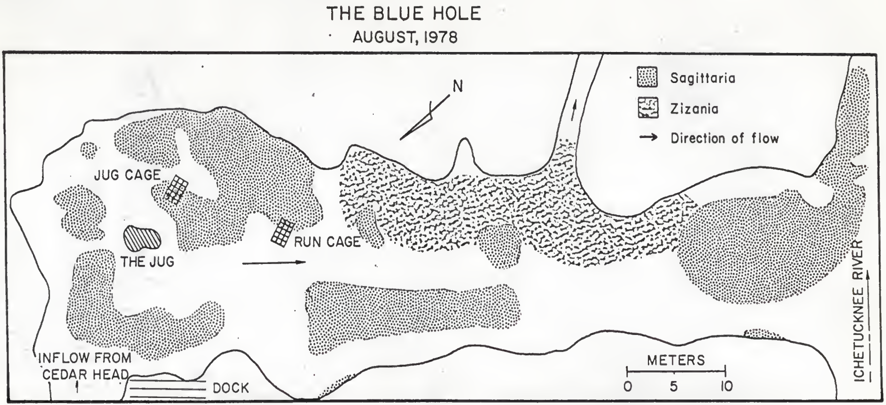


Figure 5. Location of cages in the Blue Hole.

On July 6, about five weeks after installation, the bottom of the Run Cage was photographed to determine changes in plant cover. The substrate level was also measured to determine how much sediment was deposited during this period.

At the end of the summer, the *Sagittaria* growth that had colonized the open sand area during the recovery period (May 29 to September 12) was mapped and then harvested (whole plants) to determine the net increment of *Sagittaria* cover and biomass in the Run Cage. Additionally, samples of *Sagittaria* leaf blades were clipped from two quadrats, one placed inside, the other outside the Run Cage.

In the lab, the harvested *Sagittaria* plants were measured and oven dried (70°C) to constant weight. The leaves from the inside-outside samples were counted, measured, and then oven dried.

Jug Cage. The cage situated on the south side of the Blue Hole Pool, called Jug Cage, covered a portion of a *Sagittaria* bed that had been subject to heavy disturbance prior to protection. On July 6, about a week after the cage was installed, leaf blades were clipped from quadrats placed inside and outside the cage. Two months later (September 11), two new quadrats were cut to determine changes in community structure (plant height and biomass) in both disturbed and caged sections of the *Sagittaria* bed. Leaves sampled in July were oven dried (70°C) to constant weight. Leaves from the September samples were counted and measured prior to dry weight determination.

Response to Repeated Cutting

Sagittaria kurziana, the most abundant plant in the Ichetucknee River, was used for an experiment on the effect of repeated disturbance on plant growth. Three replicate plots were used for each of three treatments applied to *Sagittaria* plants growing in a protected bed within the Devil's Eye Exclosure. All nine plots were subjected to the same kind of disturbance: the blades of all *Sagittaria* plants rooted within a quadrat (0.125 m^2) were cut back to the substrate level. The variable treatment factor was the number of times a set of plots was cut during a four-month interval extending from February 20 to June 13, 1978. One set was cut every two to three weeks, a second set was cut every four to six weeks, and the third was cut only once, at the start of the experiment. On June 13, all nine sample plots, representing three treatments, were recut. The subsequent regrowth was harvested approximately five weeks later on July 21 and oven dried (70°C) to constant weight.

Fauna Survey

Invertebrates

On August 5, 1978, a survey was conducted to determine the numbers and biomass of invertebrates inhabiting both disturbed and undisturbed plant beds. Figure 4 shows the location of three sampling sites in the headwaters area of the Headsprings Run. The first site, located inside the Headsprings Exclosure, had been protected from trampling for

more than two months prior to sampling. The second site, in the Second Dock Exclosure, had been undisturbed for about three weeks prior to sampling. The third site, located just downstream from the Third Dock, was an area that had been subjected to trampling right up to the time of sampling.

To minimize environmental variability, other than the degree of recreational disturbance, all sampling was done in Chara beds growing at shallow depths (less than 1 meter) along the edge of the channel. A stove pipe (diameter = 15.8 cm) was used to extract two sample plugs of plant material at each of the three sites. The pipe, sharpened before use, was thrust down through a Chara bed into the sediment below. The sample plug, containing plants, animals, and sediment, was lifted from the substrate with a flat-bottomed shovel and transferred to a fine-mesh net. The net was agitated in the water to remove fine silt and debris, then inverted into a plastic bag and returned to the lab.

In the lab, the sample material was placed in white enamel pans, and all animals visible to the naked eye were picked out and sorted into species. The animals were preserved in 5% Formalin, and the plant material was refrigerated until the sorting of all sample material was complete. The plant material was then oven dried (70°C) to constant weight, and the animals drained and air dried (½ hour) prior to counting and weighing.

Fish

To assess the impact of recreational trampling on the fish populations of the Headsprings Run, a survey was conducted on August 10, 1978, and October 13, 1978, to determine the types and numbers of fish in: 1. a disturbed area, the reach below the first dock; and 2. a protected area, the Headsprings Exclosure (Fig. 4). At each study site, a 20-meter rope was secured to an immovable object (dock piling or fence) and floated downstream. An observer, with face mask and underwater slate, slowly pulled himself upstream along the rope, recording in his progress all fish seen along the run. Both the protected area and disturbed area were surveyed twice, in alternate runs, on each survey day. The presence of other conspicuous organisms, such as crayfish or turtles, was also noted.

RESULTS

Base Map

The Base Map (Appendix E) shows the plant cover in each of the three reaches of the Ichetucknee River. Although an average of 25% of the channel in the Headsprings Run is vegetated, there is great variation in the amount of cover over the course of this reach. In areas subject to heavy recreational trampling and/or shading, plant cover may be as low as 1%. In open, less disturbed sections, cover values measured as high as 80%. Chara sp. and Zizania aquatica are the dominant plants in the Headsprings Run, each comprising about 25% of the total plant cover in this reach.

Aquatic plants cover approximately 40% of the bottom in the Blue Hole pool and run. Sagittaria kurziana is the dominant species in this area, accounting for 80% of the extant cover. Sagittaria is notably absent at Ichetucknee Spring and comprises only 3% of the plant cover in the Headsprings Run.

In the Rice Marsh, about 60% of the channel bottom is vegetated. Over small stretches of this reach, however, cover may vary from 25% to 90%. Sagittaria is the dominant plant in the Rice Marsh, accounting for 55% of the total

plant cover. Zizania and Chara cover less area, each comprising about 15% of total cover. The remaining vegetated areas are comprised of Myriophyllum and Vallisneria, each of which accounts for 5% of plant cover, and Ludwigia and Nasturtium, which form small patches along the edge of this deep reach.

The average amount of plant cover in the Floodplain Reach, measured over 66 map sections, is 22%, which is similar to the average for the Headsprings Reach. The variability of cover in this lower reach is, however, much less than that of the Headsprings Reach. In the Floodplain Reach, the lowest cover in one section is 14% (lowest cover in the Headsprings Reach is 1%). The maximum amount of cover is 32% (maximum cover in the Headsprings Reach is 80%). Myriophyllum and Chara are the two most common plants of the Floodplain Reach, accounting for 37% and 30% of total cover, respectively. As the Base Map shows, Sagittaria (20% cover) and Vallisneria (10% cover) grow along the edge of the channel in this reach.

Types and Amounts of Recreational Use

Figure 6 shows the types and amounts of monthly recreational use from January-August, 1978. It is evident that: 1. weekend use is much greater than weekday use, usually by a factor of three or more and 2. the number of visitors increases substantially during the warm summer months. On the average, about 150 people visited the Springs on a

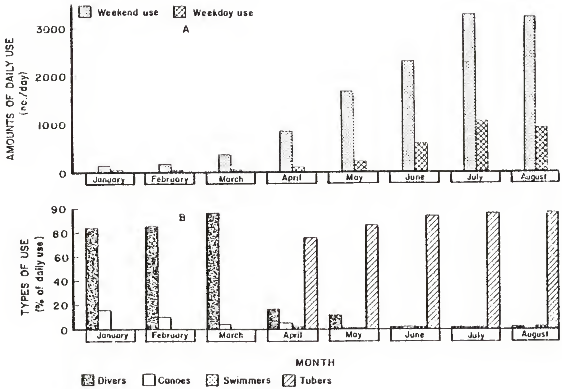


Figure 6. Types and amounts of recreational use, January-August, 1978. A. Amounts of use based on park attendance records. B. Percent of total use for each type of recreational activity. Data are based on user counts from the plant damage survey.

winter weekend day in January. By April, average weekend use had risen to nearly 1000 visitors per day. By midsummer, the number of weekend visitors consistently reached 3000 per day, the present Park limit on recreational use.

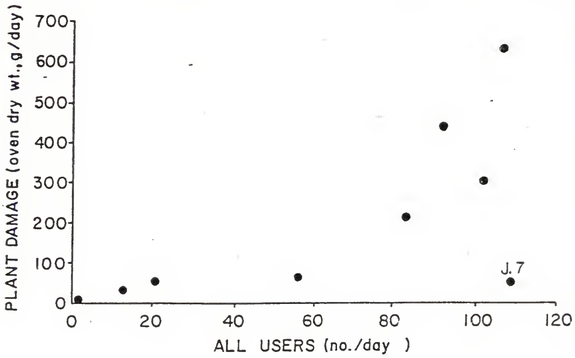
Figure 6B shows that divers constitute about 85% of the total number of winter users. Canoes account for about 10%, and swimmers and tubers comprise 5% of the total winter use.

The onset of warm weather in April signals the start of the tubing season. The proportion of tubers jumped from 10% of total use in March to 60% in April, and continued to increase during the spring. By June tubers accounted for 95% of total recreational use. This level of tubing activity was sustained throughout the summer months.

Plant Damage Survey

Winter Survey

The relationship of winter plant damage to: 1. total number of users (includes all types of recreationists) and to 2. number of divers (includes only scuba divers and snorklers) is shown in Figure 7. Examination of this figure shows that the relationship of damage to total number of users is not consistent. This lack of relationship, in effect, is best explained by the observation that canoeists, who were included in the determination of total amounts of use, generally have very little impact on the submerged plant communities of the river. Underwater assistants on



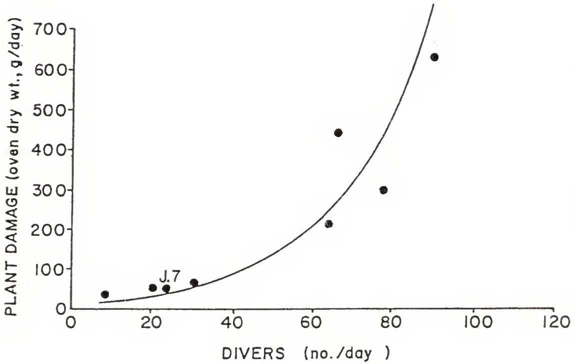


Figure 7. Winter plant damage related to total number of users and to number of divers. Relationship of plant damage (y) to number of divers (x) is described by the exponential equation,

$$y = 14.4e^{0.04x} \quad (r^2 = 0.89).$$

The notation "J.7" indicates the data point for January 7 which is mentioned in the text.

a number of occasions, watched canoes pass over plant beds. Although paddling stirs the surface of the beds, it results in very little stem or leaf breakage, and practically no uprooting. On days when canoeists constitute a large proportion of total use, as occurred on January 7 (66 canoeists, 24 divers, 15 tubers, and 4 swimmers) plant damage was expectedly very light.

The relationship of damage to number of divers (Fig. 7), shows that plant damage predictably increases as winter diving activity increases. As the number of divers increases, the amount of tearing and uprooting increases exponentially. Less than 50 dry grams of plant material was netted on days when less than 40 divers were counted. On busier sampling days, when the number of divers ranged from 60 to 100, the weight of the netted material ranged from 200 to 600 dry grams, a disproportionate increase relative to the amount of use.

Species damage. Figure 8 shows the amounts of species damage over varying levels of diving activity. One species, *Sagittaria kurziana*, accounted for 40% of the total weight of plant material collected during the winter survey. The relationship of *Sagittaria* damage to the number of divers is similar to that of total plant damage and divers in that impact accelerates when more than 60 divers use the resource. Damage to the other species is less predictable over varying levels of diving activity. When the amounts of damage to

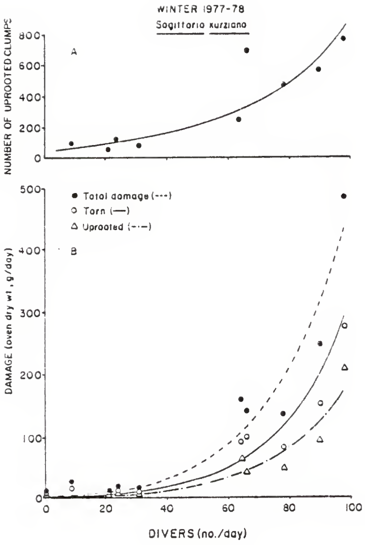


Figure 8. Damage by species, related to number of divers, Winter, 1977-78. For Sagittaria kurziana, the relationship of damage (y) to number of divers (x) is described by an exponential equation: number of clumps uprooted, $y = 50.7e^{0.3x}$ (r^2=0.83); torn fragments, $y = 1.5e^{0.06x}$ (r^2=0.74); uprooted clumps, $y = 2.7e^{0.04x}$ (r^2=0.86).

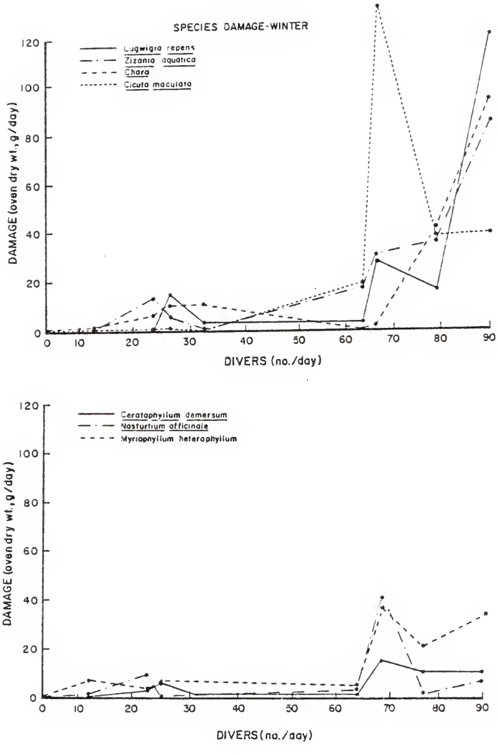


Figure 8. Damage by species, related to number of divers, Winter, 1977-78 (continued).

these species is considered collectively, however, it is again evident that when the number of divers exceeds 60, there is a marked increase in the amount of tearing and uprooting of river plants.

Figure 9 shows, for each species, the percentage of total damage and the percentage of total standing crop. It is important to note that both damage and standing crop values are estimates. The amount of plant drift netted is undoubtedly less than the amount of plant material actually torn or uprooted, and standing crop estimates are based on a limited number of samples. The figure suggests that for most species the amount of damage is proportional to standing crop.

Chara appears to be an outstanding exception to this assumption, in that the small amount netted is not proportional to its large standing crop. This disproportion is likely due to the difficulty of collecting this species. Unlike other plants, *Chara* rolls on the bottom of the channel, making it especially difficult to spot and retrieve on busy days when the water turns nearly opaque with suspended sediment.

Ludwigia and *Myriophyllum* also appear to be exceptions to the assumption that damage is proportional to standing crop. As both *Ludwigia* and *Myriophyllum* could be netted fairly efficiently, it appears that they may be selectively damaged. *Ludwigia* accounted for 15% of the total weight of

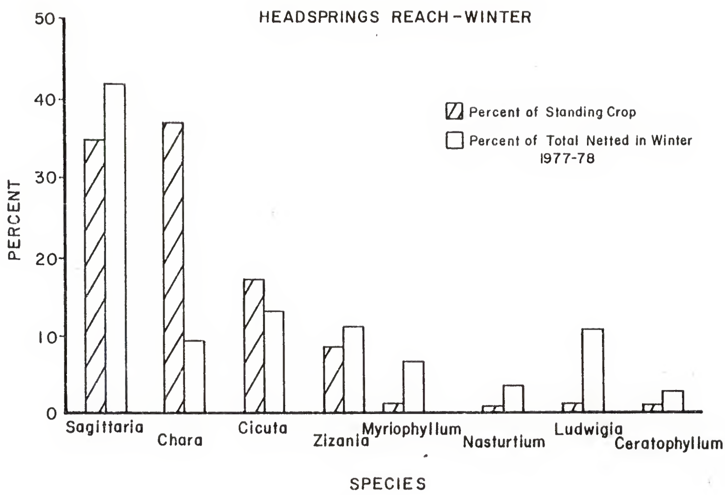


Figure 9. Percent total damage and percent of total standing crop (total weight of plants in the Headsprings Reach) of species netted in Winter, 1977-78.

plant material netted during the winter damage survey. However, the standing crop of Ludwigia comprises less than 1% of the total standing crop of the Headsprings Run and Blue Hole area. Myriophyllum comprised 7% of the total damage, but like Ludwigia, accounts for about 1% of the total standing crop.

Although Sagittaria accounted for 40% of the total damage, it also accounted for 35% of the total standing crop.

Summer Survey

Figure 10 shows the relationship of plant damage to the amount of daily recreational use in the three reaches of the Ichetucknee River. The largest amounts of drift were netted from the Rice Marsh reach. Similar amounts of vegetation, about 2000 dry grams, or 45 lbs. fresh weight, were netted on May 21 and June 14, when 1500 and 500 people, respectively, were counted. On July 9 and August 5, when 2200 and 2700 users were counted, the amounts of damage more than doubled; about 4500 dry grams, or 100 lbs. fresh weight, was collected on each of these days.

The amount of drift netted from the Floodplain Reach was much less than the amounts netted from the Rice Marsh. On June 14, 810 users were counted and about 1000 grams netted. On May 21 and July 9, at use levels of 2024 and 2056, 2744 and 2322 grams of plants were netted. The plant drift collected on August 5, when over 3000 users were

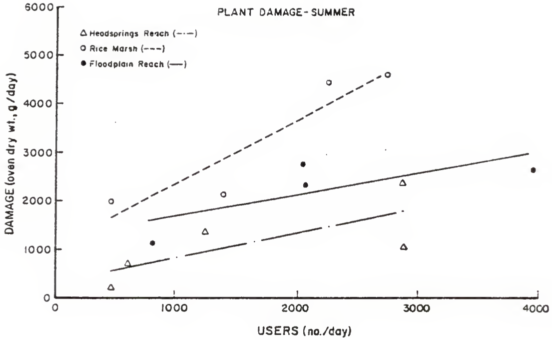


Figure 10. Amounts of daily plant damage and daily use in three reaches, Summer, 1978. Relationship of damage (y) to users (x) for each reach is described by a linear equation: Headsprings Reach, $y = 307.5 + 0.53x$ ($r^2 = 0.57$); Rice Marsh, $y = 1000.1 + 1.32x$ ($r^2 = 0.86$); Floodplain Reach, $y = 1250.0 + 0.43x$ ($r^2 = 0.55$).

counted in this reach, weighed 2637 grams, an amount similar to that netted during the 2000-user days in May and July.

The amounts of vegetation netted from the Headsprings Reach generally weighed less than the drift collected from the other two reaches. Figure 10 shows that in the 500 to 1500 user range, plant damage consistently increased with use. However, the amount of drift netted on the two 3000-user survey days varied greatly. On Sunday, July 9, 2851 users were counted, and about 2400 grams collected. On Saturday, August 5, the amount of use (2864) was similar, yet the amount of drift collected, 1083 grams, was less than half the amount netted on July 9.

Figure 11 shows that, for all three reaches, the amount of plant damage generally increased over increasing levels of hourly recreational activity. However, the variability of the results makes it difficult to predict the amount of damage for a specified level of use. Despite this variability, it is evident that over similar amounts of hourly use, plant damage in the Rice Marsh was greater than the damage in the Floodplain Reach or Headsprings Reach.

Figure 12 is similar to Figure 10, but describes damage in each reach as a fraction of the total standing crop of that reach. This figure clearly shows that recreational use generally removes a much larger fraction of the standing crop of the Headsprings Reach than it does in the middle and lower reaches. One notable exception occurred

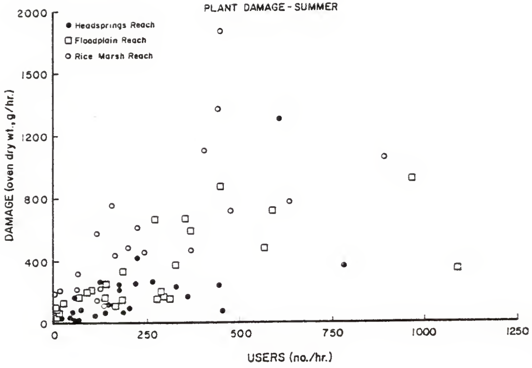


Figure 11. Amounts of hourly plant damage and use in three reaches, Summer, 1978.

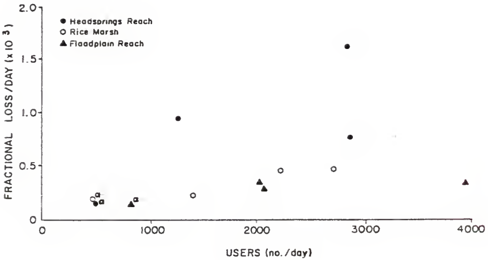


Figure 12. Number of users and fractional loss of standing crop, for three reaches, Summer, 1978.

Fractional loss =

$$\frac{\text{total damage/day (oven dry wt., grams)}}{\text{standing crop (oven dry st., grams)}}$$

The letter "a" indicates data points for June 14 which is mentioned in the text.

on June 14, the only weekday sampled, when the damage was low, and about the same, for all three reaches.

Species damage. Figure 13 shows the percentage damage and percentage standing crop of each of the major species in the three reaches of the Ichetucknee River.

In the Headsprings Reach, the amount of damage to a species was generally proportional to the size of its standing crop (see *Sagittaria*, *Zizania*, *Myriophyllum*, *Ludwigia*, and *Nasturtium*). A few species, however, sustained disproportionate amounts of damage. The percent *Cicuta* damage (22%) was twice as large as its percent standing crop (11%). In contrast, the percent *Chara* damage (8.1%) was less than half its percent standing crop (25%). As previously stated, the data for *Chara* reflect the difficulty of netting this species.

For most Rice Marsh species, the amounts netted were generally proportional to their standing crops. *Chara* was, again, an exception (1% damage, 20% standing crop). *Vallisneria* was another, but the amount netted (25% total damage) was disproportionately large relative to its standing crop (5% standing crop).

In the Floodplain Reach, percent total damage was similar to percent total standing crop for most species except *Myriophyllum* and *Sagittaria*. Whereas *Myriophyllum* appears to be selectively damaged (37% damage, 16% standing crop), *Sagittaria* appears to sustain relatively little impact in this reach (16% damage, 30% standing crop).

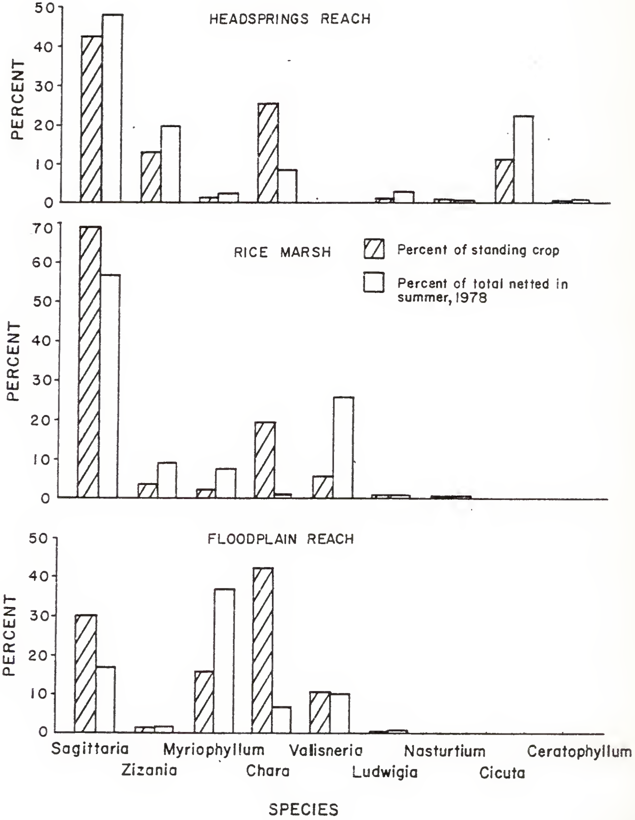


Figure 13. Percent total damage and percent of total standing crop (total weight of plants in each reach) for plant species in three reaches, Summer, 1978.

Plant Resistance

Figure 14 shows the average amount of spring force required to tear or uproot the stems of several aquatic species common to the Ichetucknee River. The large species, Zizania and Sagittaria, offered considerable resistance: 10 and 6 pounds (4.5 and 2.7 kg) of pull, respectively, were required to dislodge these plants. In contrast, the stems of Chara, Ludwigia, and Nasturtium tore under a light pull equivalent to about 0.3 pounds (0.1 kg) of spring force. Myriophyllum stems were moderately resistant, tearing at 0.5 pound (0.2 kg) of pull.

Figure 14 also shows a large variability among the individual plants tested for each species. Resistance measurements on several different-sized plants showed that smaller and/or shallow-rooted Zizania and Sagittaria plants pulled free from the substrate much more readily than plants which were buried under a layer of sediment. In fact, stems buried at depths greater than 10 centimeters could not be dislodged. Under increased pull the leaf clusters of deeply buried plants tore free at the soil surface, leaving the perennial stems intact below.

Changes in Plant Cover

Figure 15 shows the changes in plant cover in three sections of the Headsprings Run over two successive seasons (winter and summer) of recreational use. It is evident that a substantial amount of vegetative regrowth occurred between November-December, 1977, and April, 1978, and that over the

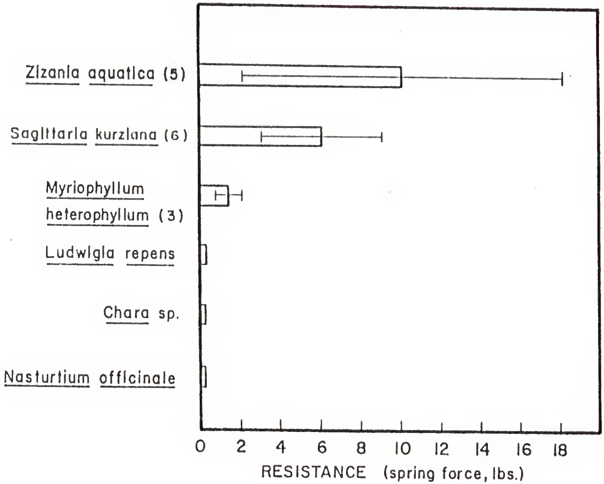


Figure 14. Resistance to tearing and uprooting. The resistance of several species was measured as the amount of spring stretch required to tear or uproot a plant. Bars show mean response and lines (|——|) show standard deviations for species subjected to several trials, the number of which are shown in parentheses. A pound of resistance is equal to 0.45 kilograms of spring force.

MAP SECTION H

11-18-77

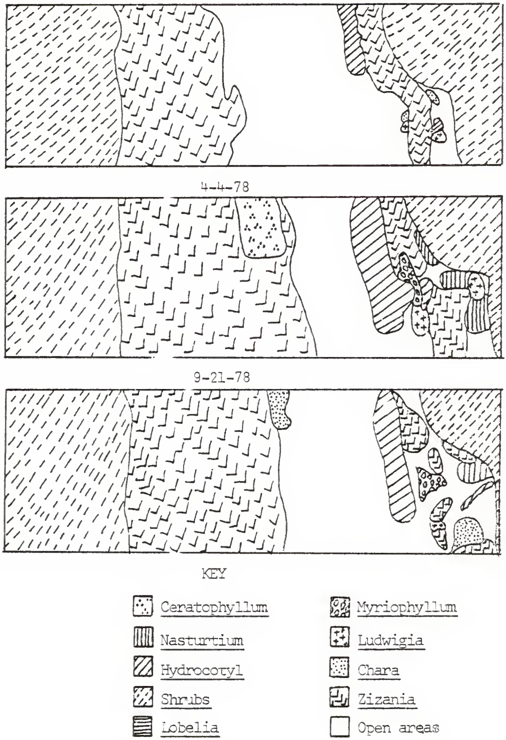
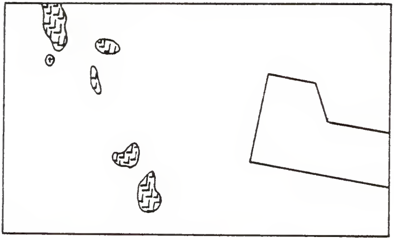


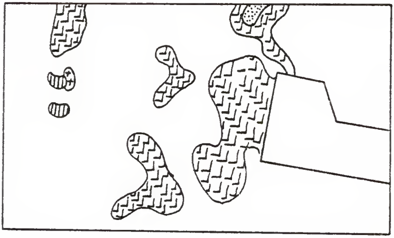
Figure 15. Seasonal changes in plant cover in three sections of the Headsprings Run. Section H, 5 meters in length, is located immediately downstream of the First Dock. Sections Q and R, each 10 meters in length, are contiguous and are located opposite and just below the Third Dock.

MAP SECTION Q

12-12-77



4-4-78



9-21-78

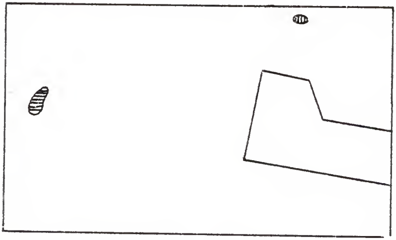
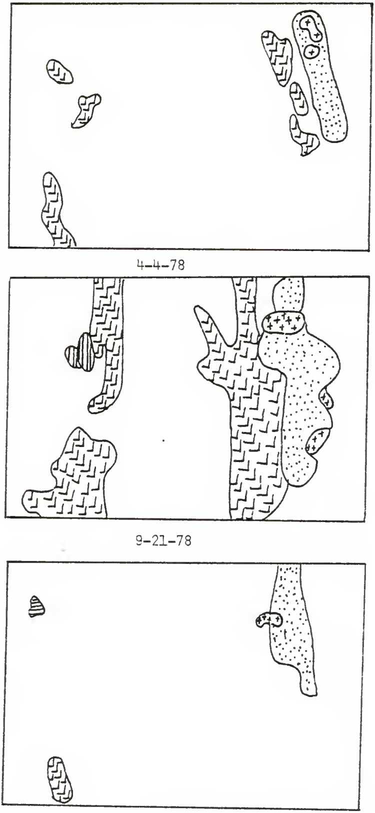


Figure 15. Continued.

MAP SECTION R

12-2-77



4-4-78

9-21-78

Figure 15. Continued.

following summer these same sections sustained a heavy loss of plant cover.

Map sections Q and R show the winter recovery and summer loss of Chara and Zizania cover in the Third Dock area. Planimetric measurements showed that Chara cover in section R increased about 12 m^2 over the winter, but decreased about 9 m^2 over the following summer. Zizania cover, almost non-existent in section Q in December, 1977, increased greatly in this area over the winter. However, this new growth was trampled back during summer 1978 to about the same level as was originally mapped the previous November.

Hydrocotyle and Ceratophyllum, two minor species components of the Headsprings Run, showed a large amount of growth in section H between November, 1977, and April, 1978. The increased coverage of these two species, as well as that of Zizania, resulted in a narrowing of the open channel floor from about 4 meters in November to about 2 meters in April. Nearly all of the Ceratophyllum winter growth, as well as a considerable amount of Zizania, was trampled out the following summer, resulting in an enlargement of a channel width to about 3 meters by September, 1978.

Experimental Plots

Sagittaria

Two trends are apparent in Table 3 and Figures 16-18, which show the results of the Sagittaria growth experiment

Table 3. Regrowth of aquatic plants following cutting or uprooting. In cut plots, all stem and leaf material was clipped back to substrate level. In uprooted plots, all rooted plants were pulled from the substrate. The biomass values represent the mean sample weight (g/m^2) and standard deviation of: 1. the above ground material that was recovered by vegetative regrowth in cut plots; 2. both the above and below ground (rhizomes, roots) material that was recovered by colonization in uprooted plots. Both harvest and indirect methods (Appendix A) of biomass measurement were used to determine these values. The growth rate (g/m^2/day) was determined by dividing biomass change between successive sampling dates by the length (days) of the sampling interval.

Species	Number of Plots	Treatment	Time	Biomass (Oven Dry Wt.) g/m^2	Growth Rate (Oven Dry Wt.) g/m^2/Day
Sagittaria kurziana	3	Uprooted	2-20-78	0.0	
			3-21-78	10.8 ± 0.5	0.03
			4-30-78	16.9 ± 9.1	0.40
			6-31-68	193.7 ± 72.8	4.02
	3	Uprooted	6-18-78	0.0	
			7-28-78	34.0 ± 8.9	0.85
			8-28-78	154.5 ± 29.4	3.88
	3	Cut	2-20-78	0.0	
			3-22-78	13.9 ± 5.8	0.46
			4-30-78	50.9 ± 6.9	1.24
			6-13-78	278.9 ± 34.5	3.52
	3	Cut	6-18-78	0.0	
			7-28-78	119.2 ± 14.8	2.98
	3	Cut	7-28-78	0.0	
			8-28-78	99.2 ± 11.3	3.20

Table 3. Continued.

Species	Number of Plots	Treatment	Time	Biomass (Oven Dry Wt.) g/m^2	Growth Rate (Oven Dry Wt.) g/m^2/Day
Myriophyllum hertophyllum	2	Cut	2-22-78 3-23-78	0.0 98.4 ± 6.8	3.39
	2	Cut	3-30-78 5- 6-78	0.0 183.2 ± 3.7	4.95
	2	Cut	5- 6-78 7- 7-78	0.0 200.8 ± 39.3	3.23
	1	Cut[a]	6-12-78 4-25-78	0.0 222.4	5.05
Chara sp.	2	Cut	2-25-78 3-25-78	0.0 371.2 ± 49.8	13.25
	2	Cut	3-25-78 5- 6-78	0.0 519.2 ± 116.5	12.36
	2	Cut	5- 6-78 7- 7-78	0.0 480.0 ± 208.2	7.74
	2	Cut	8-10-78 9- 6-78	0.0 124.8 ± 83.7	4.6
Vallisneria americana	1	Uprooted[b]	8-15-78 9-26-78	27.2	0.65
	2	Cut	8-15-78 9-26-78	50.0 ± 36.8	1.19

Table 3. Continued.

Species	Number of Plots	Treatment	Time	Biomass (Oven Dry Wt.) g/m^2	Growth Rate (Oven Dry Wt.) g/m^2/Day
Zizania aquatica	1	Cut	6-12-78		
			7-25-78	24.6	0.61

[a]Cut from a bed in the Headsprings Exclosure.

[b]A second uprooted plot, which failed to produce any new plants, is omitted from this table.

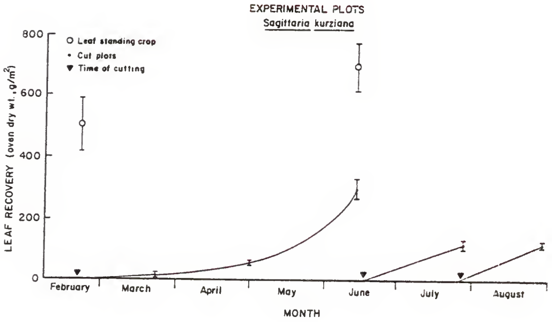


Figure 16. Standing crop and recovery of Sagittaria leaves following cutting. Bars show standard deviations of means based on three replicate plots (0.125 m^2).

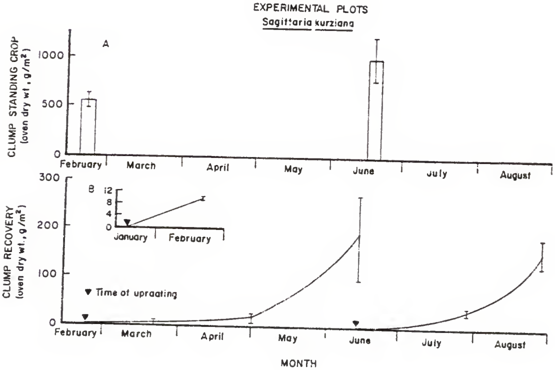


Figure 17. Standing crop and seasonal recovery of Sagittaria clumps following uprooting. Bars (├──┤) show standard deviations of means based on three replicate plots (0.125 m^2).

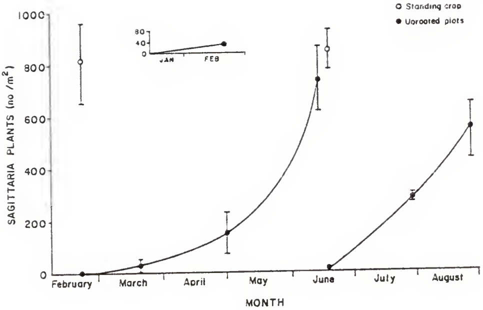


Figure 18. Number of Sagittaria clumps counted in quadrats following uprooting, and standing crop (no. of clumps) in undisturbed quadrats sampled in February and June, 1978.

conducted at the Devil's Eye Exclosure: 1. The rate of regrowth following disturbance is much greater in summer than winter. 2. Plots in which only above-ground parts (leaf blades) were cut regrew more rapidly than plots in which all plant material (leaves, stems, and roots) was removed from the substrate.

Winter growth. Inspection of Table 3 shows the differences in winter growth rates between cut plots and uprooted plots. On March 21, about one month after the initial disturbance (Feb. 20), the uprooted plots contained, on the average, about 1 gram of biomass/m^2. Over the same period, the cut plots had produced about 13 grams of new leaves. On June 13, nearly four months after the plots were first disturbed, leaf material harvested from cut plots weighed about 300 grams/m^2, while whole clumps, harvested from uprooted plots, weighed about 200 grams/m^2.

These results indicate that, following an initial lag period (Feb.-March), clump production proceeded relatively rapidly, reducing the magnitude of biomass differences between the uprooted and cut plots.

Summer growth. The growth of *Sagittaria* clumps in uprooted plots is much more rapid in summer than winter. On July 28, 40 days after three sample plots were initially uprooted (June 13), the mean weight of the new growth was about 35 grams/m^2 (Fig. 17). In contrast, plots uprooted

in February had produced less than half this amount after 70 days of regrowth. Again, as in winter, there was a more rapid accumulation of biomass in cut plots than uprooted plots. Over the 40-day period mentioned above (June 13 - July 28), the cut plots (Fig. 16) produced about 110 grams/m^2 of new leaf biomass, about three times the amount of clump biomass (35 grams/m^2) produced in the uprooted plots (Fig. 17) during the same period.

Standing crop. Results from sampling in undisturbed plots show that the standing crop of *Sagittaria* is significantly greater in summer than winter. The oven dry weight of plants (including leaves, stems, and roots) sampled on February 20 was 563.8 grams/m^2. Plants sampled on June 18 weighed 1000.6 grams, nearly a 100% increase over the winter weight (Fig. 17). The biomass of summer leaf blade samples was also significantly greater than the biomass of winter leaf blade samples (Fig. 16). The mean weight of leaf blades sampled on February 20 was 439 grams/m^2; the summer biomass was 692 grams/m^2.

Interestingly, the number of clumps in sample plots did not change seasonally (Fig. 18). On February 20, sampling showed an average of 101 clumps/m^2. On June 18, the mean number of clumps was 106/m^2, a nonsignificant increase.

Myriophyllum, Chara, Zizania

The pattern of Myriophyllum recovery was markedly different from that of Sagittaria. Myriophyllum plots cut in February regrew at about the same rate as plots cut in June (Fig. 19). Also, the relative recovery of Myriophyllum, expressed as the ratio of biomass recovered to standing crop, was greater than that of Sagittaria. Over a period extending from February 22 to March 23, Myriophyllum plots (0.125 m^2) in which all the above-ground material was clipped to the substrate level, recovered about 98 grams/m^2 of stem and leaf material, almost 60% of the original amount cut (about 170 grams/m^2). In contrast, Sagittaria plots, clipped back to substrate level on February 20, had recovered only 13 grams/m^2, or 3% of their original biomass (about 440 grams/m^2) at the time of harvest on March 21.

Chara, like Myriophyllum, recovered relatively rapidly following cutting (Table 3). Between February 20 and March 25, Chara plots in the Floodplain Reach produced, on the average, 371 dry grams/m^2 of new growth, almost 40% of the original amount cut (961 dry grams/m^2). Plots cut from a bed in the Headsprings Reach in summer did not exhibit as rapid a recovery as did the February plots at a downstream site. After a 27-day period (the recovery period for the February plots was 29 days), the Headsprings Reach plots contained, on the average, about 125 dry grams, which was only 20% of their original biomass (641 grams/m^2).

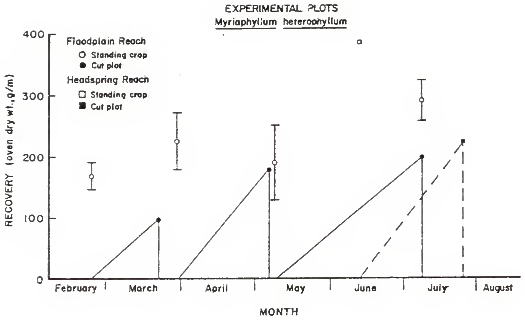


Figure 19. Standing crops and regrowth of *Myriophyllum* following cutting. On February 22, March 30, and May 6, two plots (0.125 m^2) were clipped from a bed in the Floodplain Reach and harvested after a 4-6 week recovery period. One plot (0.125 m^2) was cut on June 12 from a bed in the Headsprings Run and harvested on July 25. Bars show standard deviations of sample means.

Table 3 shows the recovery of several other species following cutting. The pattern of recovery of Zizania aquatica exemplified the ambiguity of results obtained from some of the test plots. In June, several Zizania plants in a quadrat in the Headsprings Exclosure were cut back to substrate level. A month later, none of the plants originally cut could be found, and a thick felt-like layer of algae covered the sample area. The only macrophyte observed in the quadrat was one Zizania clump, not one of those originally cut, which appeared to have emerged from the substrate during the recovery period. In contrast, several Zizania plants, cut back in the channel of the Floodplain Reach, recovered about 16 centimeters of leaf growth over a 5-day period in February.

Results from Vallisneria plots indicate that the recovery of this species may be dependent on the initial vigor of the bed. Plots which showed a relatively large standing crop prior to disturbance (cutting or uprooting), exhibited much more regrowth (Table 3) than did plots having a low standing crop.

Exclosures

Headsprings Exclosure

Figure 20 shows the change in channel profile and shifts in the positions of the dominant plant beds in a section (Site A) of the Headsprings Exclosure monitored over

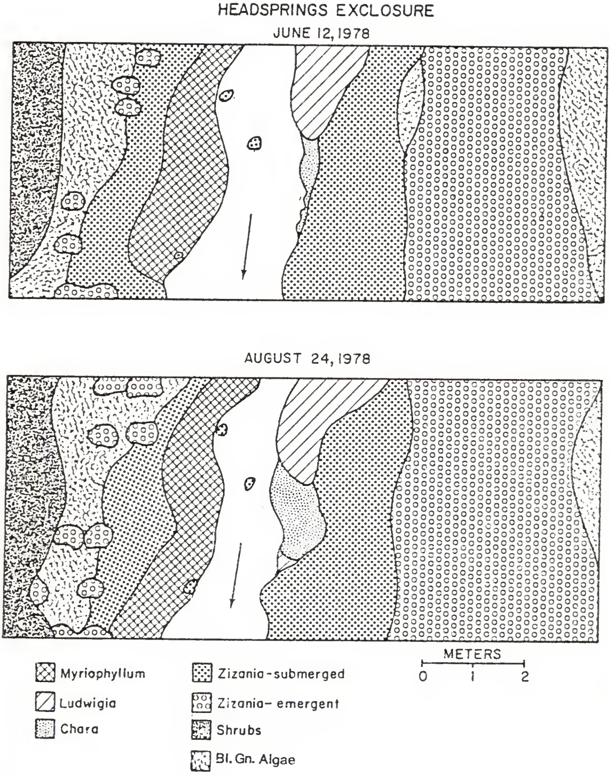


Figure 20. Change in plant cover, Site A, Headsprings Exclosure, 6-12-78 to 8-24-78.

the summer of 1978. Between June 12 and August 24, 1978, channel closure averaged about 70 centimeters over the length of this 5-meter section. As the figure and time-series photographs show (Plate 1), the vegetative expansion of several species, including *Chara*, *Myriophyllum*, *Ludwigia*, and *Zizania*, resulted in a narrowing of the channel.

Figure 21 shows the change in channel profile of a second exclosure section (Site B), located just upstream of the 5-meter map section. The average amount of closure, measured at one-meter intervals over this 10-meter section, was about 40 centimeters over a two-month period in summer. A notable feature, evident in both the 10 and 5 meter sections, is an increase in profile irregularity as natural forces become more important than human disturbance in shaping the growth patterns of submerged plant beds.

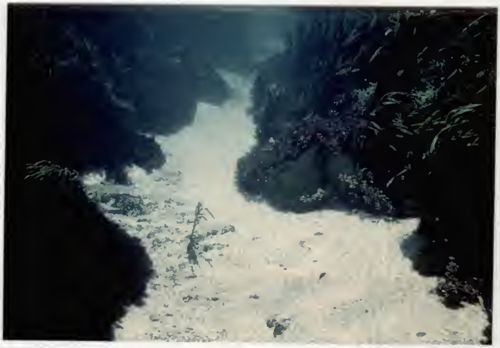
Second Dock Exclosure

The change in plant cover in eight 1 m^2 quadrats, protected from recreational disturbance by the fenced exclosure opposite the Second Dock, is shown in Figure 22. Between July 24 and October 26, plant cover increased in four of the quadrats, but showed little change in the others.

Quadrats 1, 3, and 6, which contained largely bare sand prior to exclosure, remained in essentially the same condition over the measurement period. Small patches of blue-green algae shifted in position, but did not increase the plant cover in quadrats 1, 2, and 3. In fact, the only

Plate 1. Headsprings Exclosure, July and November, 1978. This section of the channel, lying immediately above the downstream fence was photographed from approximately the same position one month after the exclosure was erected (A) and four months later in November (B). Several changes are apparent: the growth of individual plant patches, the closing of the open channel, and the diversity and beauty of a protected reach.

A



B

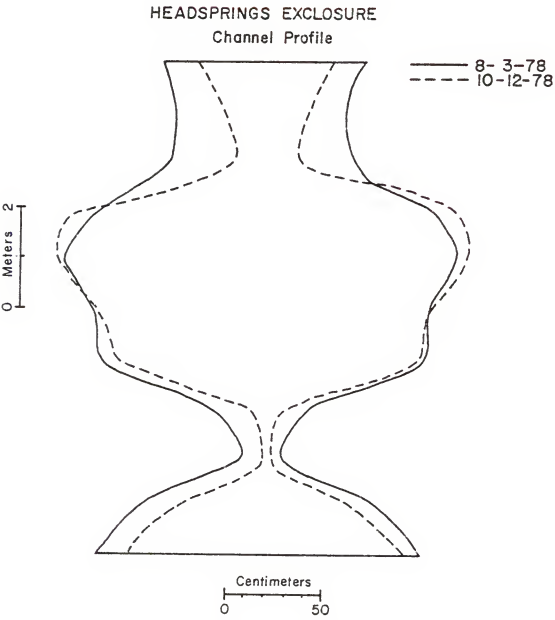


Figure 21. Change in channel profile, Site B, Headsprings Exclosure, 8-3-78 to 10-12-78.

SECOND DOCK EXCLOSURE

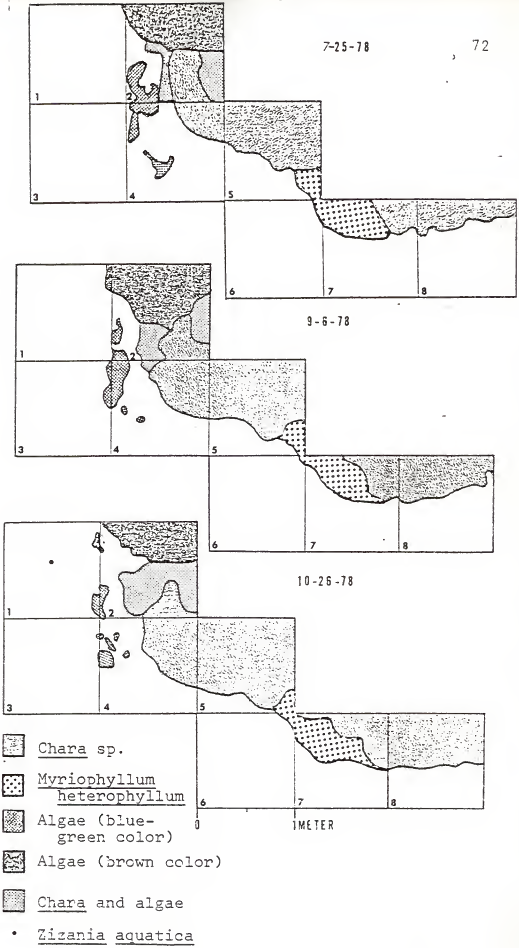


Figure 22. Change in plant cover, Second Dock Exclosure, 7-25-78 to 10-26-78.

evidence of new plant growth in 1, 3, and 6, was a *Zizania* seedling, which appeared in quadrat 1 at the time of the third mapping on October 26. Quadrat 2, tucked in a quiet shallow, appeared to be dominated by algal growth which showed a slight decrease in coverage during the study.

The vegetative cover in quadrats 4, 5, 7, and 8 increased considerably between July and October. On June 25, the date of the first mapping, *Chara* covered about 1.1 m^2 of the bottom in this four-quadrat section; 43 days later, on September 6, *Chara* cover measured 1.6 m^2, representing an average rate of increase of 115 cm^2/day.

On October 26, *Chara* beds covered 2.0 m^2 of the 4.0 m^2 section, having grown at an average rate of 80 cm^2/day since September 6.

Myriophyllum cover did not change much over a three-month period. On July 25, *Myriophyllum* cover in quadrats 4, 5, 7, and 8 was 0.25 m^2; on October 26, this species covered 0.26 m^2, a negligible increase.

Figure 23 shows that the number of *Zizania* plants in a fixed quadrat did not change between August 3 and September 26, 1978. However, the size of the individual plants did increase. On August 3, the mean length of *Zizania* plants was 66 centimeters. On September 26, mean plant length was 77 centimeters.

The change in plant cover observed in this 1 m^2 quadrat was almost entirely due to the vegetative expansion of *Chara*.

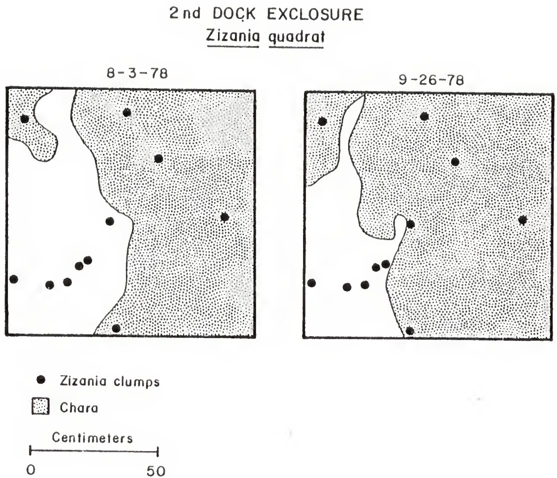


Figure 23. Growth of *Zizania* and *Chara*, Second Dock Exclosure.

Blue Hole Cages

Jug Cage

Results from the Jug Cage in Blue Hole are summarized in Figure 24. On June 6, shortly after the Jug Cage was installed, the amount of *Sagittaria* leaf biomass in a sample taken inside the cage (240 grams/m^2) was about the same as the amount of leaf biomass in a sample taken from the *Sagittaria* bed surrounding the cage (220 grams/m^2). On September 11, after two months of protection, a sample of leaf blades clipped from within the cage weighed over 300 grams/m^2, whereas the biomass of a sample taken from the unprotected area outside the cage was less than 200 grams/m^2.

The biomass differences of the inside-outside cage samples can be attributed to differences in the size of individual leaves, not in the number of leaves. As Figure 24 shows, the number of leaf blades in the sample clipped from the floor of the cage on September 11 was actually less than the number of leaves in the sample taken from outside the cage. The length of leaves inside the cage, however, was much greater than leaf lengths in the surrounding bed.

Figure 24A, describing the frequency distribution of leaf lengths, shows that the lengths of cage leaves were distributed relatively evenly over size classes ranging from 0-9 to 80-89 centimeters. In contrast, the leaf lengths of the outside sample showed a skewed distribution with a modal size class of 10-19 centimeters and class range of 0-9 to 50-59 centimeters.

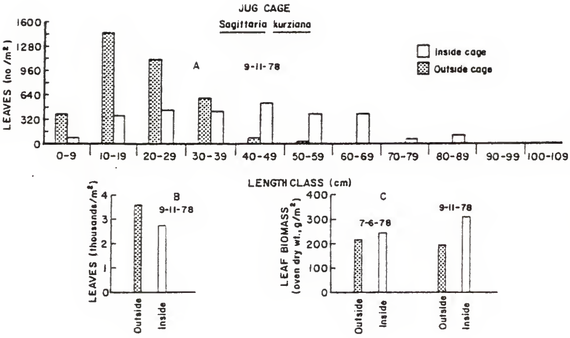


Figure 24. Characteristics of Sagittaria leaves sampled both inside and outside of Jug Cage. A. Size distribution of inside-outside leaf samples. B. Numbers of leaves of inside-outside samples. C. Weight of leaves of inside-outside samples.

Run Cage

The biomass, number, and size of Sagittaria leaves cut inside and outside the Run Cage are shown in Figure 25. The number of leaves in the two samples were about equal, but they differed greatly in size and biomass. After three months of protection, cage leaves weighed about 450 grams/m^2, and were distributed over a wide range of length classes with maximum lengths between 100 and 109 centimeters. The Sagittaria leaves in the surrounding bed appeared to be stunted. They averaged about 25 centimeters in length, and measured only 60 centimeters at the maximum. The biomass of the outside sample was about 300 grams/m^2, considerably less than the inside sample.

Over the summer (May 29 to September 12), Sagittaria plants colonized 0.55 m^2 of the open sand area in the Run Cage (Fig. 25). The 347 new clumps produced during this period accounted for a net biomass accumulation of 202.7 grams. As is evident in the figure, the increase in Sagittaria cover was greater on the downstream side of the cage than on the side facing the flow.

Another feature which distinguished the inside cage sample from the outside sample was the color and texture of leaf blades. Leaves cut from the cage were bright green and smooth. Leaves from the surrounding bed were brownish and gritty. Results from ashing showed that the organic weight of cage leaves was about 83% of their dry weight;

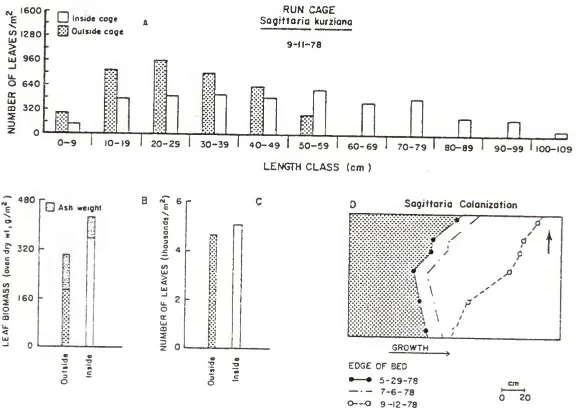


Figure 25. Sagittaria colonization and characteristics of leaves sampled both inside and outside of the Run Cage. A. Distribution of leaf lengths of inside-outside samples. B. Weight of leaves of inside-outside samples. C. Numbers of leaves of inside-outside samples. D. Colonization of open cage bottom by Sagittaria plants.

the organic weight of leaves sampled outside the cage was only about 63% of dry weight. Microscopic inspection of the residue remaining after ignition showed, for the cage sample, a clean white ash. The residue from the outside sample was grayish in appearance, and consisted of relatively large sand grains in addition to ash and other mineral matter.

Sediment Deposition

There was a considerable buildup of sediment in both cages following installation. In the Jug Cage, sediment depth increased 5.8 centimeters between May 29 and July 6, 1978. In the Run Cage, sediment depth increased 1.4 centimeters between May 29 and June 30.

Response to Repeated Cutting

Figure 26 shows the regrowth patterns of *Sagittaria* plots subjected to varying intensities of cutting over a four-month period extending from February 20 to June 13, 1978. Plots that were cut six times previous to the test recovery period (June 13 to July 21) regrew just as rapidly as plots that were cut three times or only once. The figure also shows that the average growth rate (slope) of plants cut every two to three weeks increased after each successive cutting.

Following the first cut on February 20, *Sagittaria* leaf blades grew back at an average rate of 0.48 grams/m^2/day

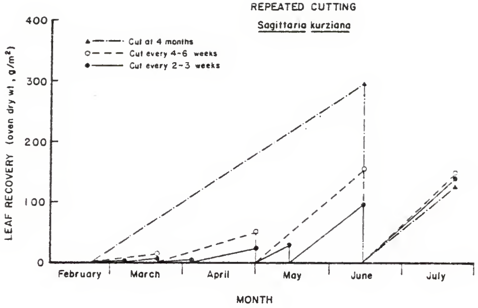


Figure 26. Sagittaria leaf recovery in plots subjected to repeated cutting. Three plots (0.125 m^2) were used for each of three treatments: 1. plots cut every 2-3 weeks, 2. plots cut every 4-6 weeks, and 3. plots cut after four months.

over the ensuing 15-day period. The same plots recovered at an average rate of 3.7 grams/m^2/day after the last cutting on June 13. This rate is comparable (no significant difference) to the rates of 3.6 and 3.8 grams/m^2/day measured for plots cut three times and only once, respectively, prior to the test recovery period. The growth rate of three new plots, cut on June 18 and harvested July 28, was 3.0 grams/m^2/day.

Fauna Survey

Invertebrates

Mollusks. Table 4 summarizes the results of the invertebrate sampling in areas subject to varying degrees of disturbance. The table shows that one of the samples from the Headsprings Exclosure (No. 1), which at the time of the survey had been undisturbed for over two months, contained more species (4) and greater numbers (about 17,000/m^2) and biomass (about 720 grams/m^2, including shell weight) of mollusks than any other sample. Each of the other five samples contained fewer species, and less than half this number or biomass. Of these, the sample taken from the moderately disturbed *Chara* bed below the Third Dock (No. 5) contained the greatest snail biomass. The number of snails in the other Third Dock sample site (No. 6), a badly torn *Chara* bed, was similar to the number found in a sample (No. 4) taken from a less disturbed bed in the Second Dock Exclosure.

Table 4. Plant biomass and number and weight of mollusks and arthropods sampled in three areas subject to varying degrees of recreational disturbance. Two samples were taken from *Chara* beds at each site in August 1978. The Headsprings Exclosure had been fenced two months, and Second Dock Exclosure about three weeks prior to sampling. The Third Dock area was unprotected and subject to trampling prior to the sampling day. The diameter of the pipe was 15 cm; the area sampled was 0.0177 m^2.

MOLLUSKS

Location	Sample No.	Chara (Oven Dry Wt., gms)	Goniobasis No.	Goniobasis Weight[a] (g)	Campeloma No.	Campeloma Weight (g)	Physa No.	Physa Weight (g)	Helisoma No.	Helisoma Weight (g)	Total Mollusks No.	Total Mollusks Weight (g)
Headsprings Exclosure	1	9.3	214	10.26	2	0.57	87	1.89	1	.02	304	12.74
	2	18.3	86	4.57	0		0		0		86	4.57
Second Dock Exclosure	3	10.5	48	2.45	0		10	0.19	0		58	2.64
	4	8.3	97	5.00	0		1	0.02	0		98	5.02
Third Dock Exclosure	5[b]	10.6	96	7.52	0		0		0		96	7.52
	6[c]	1.6	51	3.64	0		2	0.11	0		53	3.75

ARTHROPODS

Location	Sample No.	Chara (Oven Dry Wt., gms)	Palaemonetes No.	Palaemonetes Weight (g)	Cambarus No.	Cambarus Weight (g)	Other Crustaceans No.	Other Crustaceans Weight (g)	Insect Larvae No.	Insect Larvae Weight (g)	Total Arthropods No.	Total Arthropods Weight (g)
Headsprings Exclosure	1	9.3	12	0.48	1	0.37	5	0.02	0		18	0.87
	2	18.3	2	0.16	1	0.39	0		2[d]	0.14	5	0.69

Table 4. Continued.

Location	Sample No.	Chara (Oven Dry Wt., gms)	Palaemonetes No.	Palaemonetes Weight (g)	Cambarus No.	Cambarus Weight (g)	Other Crustaceans No.	Other Crustaceans Weight (g)	Insect Larvae No.	Insect Larvae Weight (g)	Total Arthropods No.	Total Arthropods Weight (g)
Second Dock Exclosure	3	10.5	14	0.67	1	0.01	0		1[e]	0.36	16	1.04
	4	8.3	14	0.70	0		0		1[f]	0.02	15	0.72
Third Dock Area	5	10.6	7	0.29	5	0.47	0		1[g]		13	0.76
	6	1.6	2	0.01	0		0		2[h]	0.07	4	0.08

[a]Fresh weight after draining preserved snails (10% Formaldehyde) for one-half hour.

[b]Sample 5 was taken from a moderately disturbed bed near the riverbank.

[c]Sample 6 was taken from a badly torn bed at the edge of the main channel.

[d]One was an Odonate, the other Rhagovelia sp.

[e]An Odonate.

[f]An Odonate.

[g]A Trichopteran, which was not removed from its larval case or weighed.

[h]Both Odonates.

The weight and numbers of mollusks does not appear to be related to the amount of vegetation at a site. Maximum numbers and weight were found in a sample (Headsprings Exclosure, No. 1) which ranked fourth in weight of plant material. In contrast, the second sample in the Headsprings Exclosure (No. 2) contained the most plant material, but ranked fourth in both number and biomass of mollusks.

Arthropods. Table 4 shows that both the number and biomass of arthropods in the sample taken from the heavily disturbed Chara bed (Third Dock, No. 6) were considerably lower than the number and biomass of samples taken in other areas. This sample contained two insect larvae and two small shrimp, which collectively weighed 0.08 grams (sampling area 0.0177 m^2) or 4.5 grams freshweight/m^2. A second sample taken from a less trampled portion of the same bed (Third Dock, No. 5), contained a Trichopteran (Caddis fly) larvae, 5 small crayfish, and 7 shrimp, which collectively weighed 0.76 grams, or 43 grams freshweight/m^2. The biomass of arthropods sampled in the two fenced areas, the Headsprings Exclosure and Second Dock Exclosure, was about the same as that found in Third Dock, No. 5, with the exception of sample No. 3, Second Dock Exclosure, which weighed 1.04 grams.

Fish

Results of the fish survey are summarized in Table 5, which shows the types and numbers of fish and other aquatic

Table 5. Types and numbers of fish in disturbed (First Dock area) and undisturbed (Headsprings Exclosure) sections of the Headsprings Reach. On each survey day (8-10-78 and 10-13-78), an underwater observer recorded all fish seen on two alternate runs (a slow upstream swim along a submerged rope) in each area.

	HEADSPRINGS EXCLOSURE Number of Fish 8-10-78		10-13-78		FIRST DOCK Number of Fish 8-10-78		10-13-78	
	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
FISH								
Centrarchidae								
Stumpknocker - *Lepomis punctatus*	6	2	9	6	6	4	5	10
Redbreast - *Lepomis auritus*		3					1	
Other Sunfish - *Lepomis* spp.	14	31	6	17	5	1	4	4
Total Sunfish - *Lepomis* spp.	20	36	15	23	11	5	11	14
Bass - *Micropterus* spp.	8	6	14	5	1	1	1	1
Esocidae								
Redfin Pickerel - *Esox americanus*	0	0	1	1	0	1	1	1
Percidae								
Darter - *Percina* sp.	0	0	2	0	0	0	1	0
Poecillidae								
Mosquitofish - Gambusia affinis	+[a]	+	+	+	+	+	+	+
Cyprinidae								
Chub - *Hybopsis harperi*	+	+	+	+	+	+	+	+
Sucker - *Moxostoma* sp.	1	3	5	3	0	0	0	0
Chubsucker - *Erimyzon sucetta*	2	2	2	3	0	0	0	0
Golden Shiner - *Notemigonus crysoleucas*	0	0	0	1	0	0	0	0

Table 5. Continued.

	HEADSPRINGS EXCLOSURE Number of Fish 8-10-78		HEADSPRINGS EXCLOSURE Number of Fish 10-13-78		FIRST DOCK Number of Fish 8-10-78		FIRST DOCK Number of Fish 10-13-78	
	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
TURTLES								
Loggerhead Musk - *Sternothaerus minor*	0	2	1	1	0	0	0	0
Yellow-bellied - *Pseudemys scripta*	0	0	0	1	0	0	0	0
Other - *Pseudemys* sp.	0	1	0	0	0	0	0	0
CRUSTACEANS								
Crayfish - *Cambarus* sp.	0	0	0	0	0	1	1	0

[a] + indicates that a species was seen, but the numbers of fish not recorded.

organisms in protected and unprotected areas of the Headsprings Run. The majority of fish observed were represented by two families, the sunfish family, the Centrachidae, and the minnow family, the Cyprinidae. The table shows that whereas only one Cyprinid species, the common chub, Hybopsis harperi, was seen in the disturbed area below the First Dock, several members of this family, including chubs; chubsuckers, Erimyson sucetta; suckers, Moxostoma sp.; and golden shiner, Notemigonus crysoleucas were seen inside the fenced exclosure. The figure also shows that two species of turtle, the loggerhead musk, Sternothaerus minor, and yellow-bellied, Pseudemys scripta, were observed in the exclosure. No turtles were seen on four 20-meter runs in the area below First Dock.

The numbers of Centrachids also differed greatly in the two study areas. Large congregations of bass (Micropterus spp.) and bream (Lepomis spp.) were commonly observed in the Headsprings Exclosure under the shelter of aquatic plants or overhanging shrubbery. In the First Dock area, where much of the vegetation had been trampled out, the few bass and bream counted were generally observed feeding or resting alone or in pairs. Despite heavy disturbance, crayfish were seen near the First Dock during the survey. Although no crayfish were seen in the exclosure during the four survey runs, they were frequently observed in this area during work on other aspects of the study.

DISCUSSION

In the Headsprings Reach, the loss of plant cover resulting from recreational use is more visibly apparent than is the loss of cover in either the Rice Marsh or Floodplain Reach. The data show, in fact, that the percentage loss of standing crop in the Headsprings Reach is much greater than the percentage loss in the middle and lower reaches. For this reason, details of the impact of recreation on the plant communities of the Headsprings Reach are discussed first, followed by the impact of recreation on the plant communities of the Rice Marsh and Floodplain Reach; the impact of recreation on the animals of the river; and the carrying capacity for recreational use.

Impact of Recreation on the Plant Communities of the Headsprings Reach

Tuber Impact

The three sections of the Headsprings Run which were mapped in April, 1978, and remapped in September, 1978, show that there is a large loss of plant cover in this reach in summer. A more detailed analysis of the data from the plant damage survey reveals aspects of tuber impact which were not shown in the figures included in the Results section. Figures 10 and 11 in the Results section suggest that tuber

damage may actually decline during the days and hours of heaviest use. This suggestion is very misleading. The data for the busiest days and hours were collected in July and August, the last two months of the summer survey (April - August). By that time, a substantial amount of vegetation had been trampled from the channel, such that the amounts of netted plants seemed small relative to the magnitude of use.

Figure 27 shows the amounts of daily use and damage, and Figure 28, the amounts of hourly use and damage, for each of the five days surveyed in summer, 1978. Three important features of user impact are described in these figures:

1. The ratio of daily damage to daily use, or average amount of plant damage per user, declined sharply over the summer (this ratio can be roughly estimated by comparing the heights of the bars in Figure 27).
2. The ratio of hourly damage to hourly use declined over the summer (this was determined from the slopes of the graphs in Figure 28).
3. On Wednesday, June 14, the only weekday surveyed, hourly amounts of plant damage remained consistently low, and were not correlated ($r^2 = 0.01$) with the amount of hourly use.

The trends described in Figures 27 and 28 can be largely accounted for by two factors: 1. tuber behavior and 2. the physical characteristics of the Headsprings Reach.

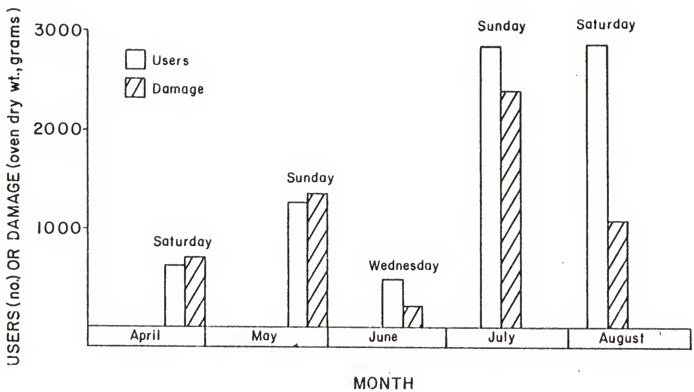


Figure 27. Amounts of daily use and plant damage, Headsprings Reach, Summer, 1978.

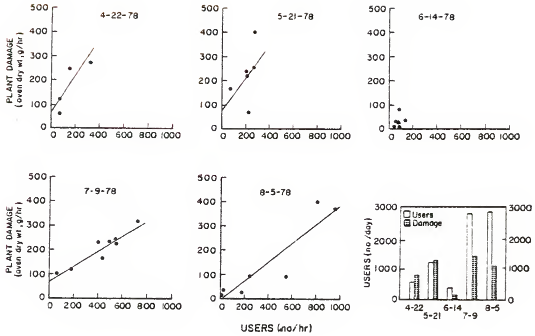


Figure 28. Amounts of hourly use and plant damage for five survey days, Headsprings Reach, April to August, 1978. For each survey day, the relationship of hourly damage (y) to hourly use (x) is described by a linear equation: 4-22-78, $y = 70.8 + 0.70x$ ($r^2 = 0.72$); 5-21-78, $y = 80.3 + 0.70x$ ($r^2 = 0.20$; 6-14-78, ($r^2 = 0.01$); 7-9-78, $y = 72.8 + 0.31x$ ($r^2 = 0.90$); 8-5-78, $y = -5.2 + 0.39x$ ($r^2 = 0.89$). A large raft of <u>Cicuta</u> (988 g, dry wt.) netted on 7-9-78 was not included in data for 11 a.m.-12 noon (733 users).

Recall that this reach averages about 10 meters in width and is generally less than 1 meter deep. On quiet weekdays, when generally fewer than 100 users enter the run each hour (see June 14, Figure 28), an individual tuber or group can enter the narrow run and proceed downstream without interference from other groups or individuals. As shown by the amounts of plant material netted, hourly damage remained consistently low, less than 50 grams, over the course of this weekday.

On summer weekends, when the amounts of hourly use range from 100/hr. to as high as 1000/hr., groups of users inevitably become tangled around the entry docks, and bottlenecks of tubers develop over the course of the Run. Unable to proceed downstream, or forced to the side of the channel, many users get off their tubes and trample through the shallow channel in their attempts to rejoin their party or resume progress downstream. The amount of hourly plant damage increases directly as the amount of trampling and congestion increases.

Another problem occurs at the junction of the Headsprings Run and Blue Hole. Many tubers, arriving at this point, choose to proceed up the Blue Hole channel against the direction of the outflow. Unable to paddle against the strong current, many get off their tubes and walk up the edge, the path of least resistance. This activity results in extensive trampling of both the plant beds and sediment banks along the edge of the Blue Hole run.

Plates 2 and 3 visually document the types of damage which have been discussed, and demonstrate, convincingly, that the decline in netted drift in the later summer months is a result of severe environmental degradation rather than a change in tuber behavior.

Species Damaged by Tubing

Figure 29, showing species damage in the Headsprings Reach in summer, illustrates other important aspects of tuber impact. Three trends can be discerned: 1. for one species, Chara, both the amount netted and its percentage of the total damage increased in the later survey months (July and August); 2. for three species, Ludwigia, Nasturtium, and Ceratophyllum, the amounts netted and their percentage of total damage decreased in the later survey months; and 3. for the remaining species, the amounts and percentages either remained fairly constant or were highly variable over the summer survey.

Chara damage. Figure 29 shows that very little Chara, generally less than 20 grams, was netted on the April, May, and June survey days. However, 100 and 330 grams were netted on July 9 and August 5, respectively. As previously stated, the data for this species are more likely a reflection of method than actual tuber impact. The substantial increase on August 5 undoubtedly resulted from an improvement in the method, which was achieved by adding a third netting assistant, specifically assigned to collect all

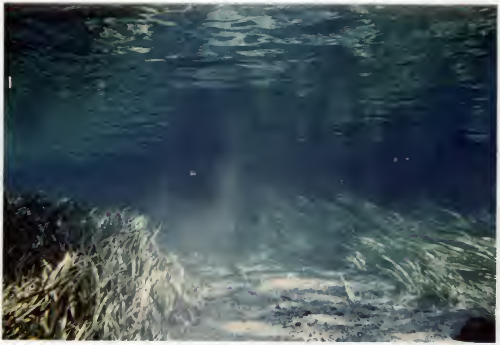
Plate 2. Tuber impact on the Blue Hole. A. Bank and bottom erosion due to trampling. B. Disturbed and protected sections of a *Sagittaria* bed showing differences in both the length and color of plant blades. In the cage, leaves measure to 1 meter in length and are light green. In the surrounding bed, average leaf length is about 0.3 meter, and the blades are discolored by adherent silt and other mineral matter.

A

B

Plate 3. *Sagittaria* bed, April and August, 1978. This bed, situated at the outlet of the Blue Hole Run, was photographed from approximately the same position at the start of the tubing season in April (A) and later in August (B). In April, the plants stood knee to waist high; by August they had been trampled down to ankle height.

A



B

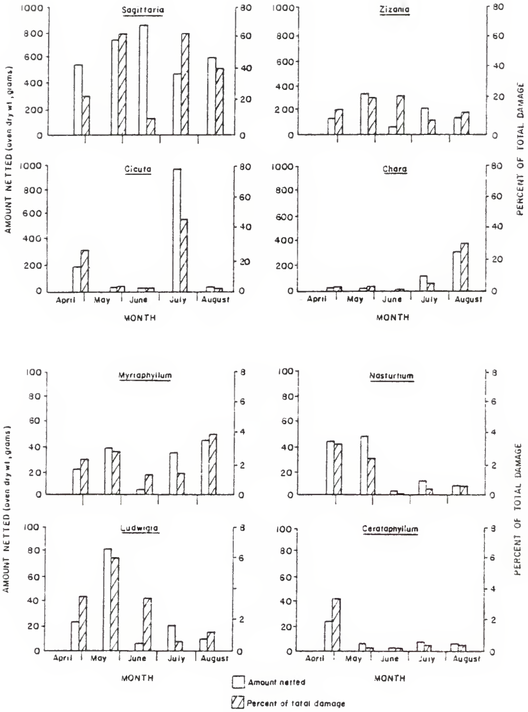


Figure 29. Species damage in the Headsprings Reach, April to August, 1978.

drift below the surface. Interestingly, under more efficient capture, the amount netted on August 5, 333 grams or 30% of the total damage, was proportional to the standing crop of this species, which was 33% of the total standing crop in the survey area.

Ludwigia, Nasturtium, and Ceratophyllum damage. Damage to Ludwigia, Nasturtium, and Ceratophyllum was heaviest in early summer, then declined over the succeeding months. Two characteristics, shared by all three species, likely account for this pattern of damage: 1. Ludwigia, Nasturtium, and Ceratophyllum have the smallest standing crops of all the species mapped in the Headsprings Reach (see Appendix D). 2. All three species possess weak stems which are vulnerable to tearing, as was shown for Ludwigia and Nasturtium in the Resistance Experiment, and as is a commonly cited characteristic of rootless Ceratophyllum (Arber 1920, Sculthorpe 1967). Because of these shared characteristics, the bar graph suggests that these three species were almost completely trampled out of the Headsprings Run in the early summer months, such that by July and August they were scarcely noted in the drift. Note that nearly 100 dry grams of Ludwigia, which is about 2.5% of the total standing crop of this species (about 4000 grams, measured in winter), was netted during a six-hour period on Saturday, May 21, 1978. The amount of Ceratophyllum netted in four hours on April 22 accounted for 2.3% of its total winter standing crop.

Assuming that as much as 4-5% of the standing crop of these plants are damaged in a single day on spring weekends, one can easily comprehend their near-eradication by mid-summer, as the survey data suggest. Note, in map section H (Fig. 15), the large loss of *Ceratophyllum* cover between April and September, and observe the disappearance of *Ludwigia* and *Nasturtium* in map sections Q and R.

Damage to other species. *Sagittaria*, *Zizania*, *Myriophyllum*, and *Cicuta* all have relatively large standing crops, ranging from 20 kilograms for *Myriophyllum* to 150 kilograms for *Sagittaria*. Although these species sustained heavy damage, inspection of the Run and Blue Hole at the end of the summer showed that some cover remained. This is evident in the August map of Blue Hole (Fig. 5), which shows *Sagittaria* growing in the center of the spring run channel and along the south edge of the pool. Like *Sagittaria*, *Zizania* sustained a heavy loss of cover in summer. Many surviving plants, however, were seen growing along the edge of the Headsprings Run the following fall.

Figure 29 shows that *Cicuta* damage was highly variable, being negligible on three survey days, but accounting for a large proportion of the total damage on the other two survey days (30% on April 22, and 45% on July 9). The variable nature of *Cicuta* damage is likely due to its growth habit. *Cicuta* beds, which grow along the edge of the channel, are comprised of numerous leafy stems interconnected

by a network of large floating rhizomes. Under light disturbance, small leaf and stem fragments may break off, but the bulk of the bed remains in place. Under heavy disturbance, however, an entire floating bed may be dislodged and set adrift. The large amount of Cicuta netted on July 9, about 1 kilogram dry weight, resulted from the displacement of a single raft of this species.

Impact of Divers on the Blue Hole in Winter

Data from both the plant damage survey and experimental growth plots strongly suggest that the Sagittaria community in the Blue Hole loses more cover in winter than it can regain by regrowth. As previously stated, the Blue Hole is a very popular winter diving area, and most of the Sagittaria damage observed there can be directly attributed to that activity.

A comparison of the amount of Sagittaria damaged by winter divers with the amounts damaged by summer tubers shows that although the overall magnitude of damage is greater in summer, the impact of an individual diver is much greater than the impact of an individual tuber. On March 3, 98 divers uprooted and tore about 500 grams of Sagittaria, an average of about 5 grams/diver. On May 21, 1200 tubers were counted and about 800 grams of Sagittaria netted from the Blue Hole area. Although the overall amount of damage was greater, the amount per user, about 0.75 gram, was much less.

Figure 30, which shows the damage and recovery rates of both uprooted and torn Sagittaria plants, clearly illustrates the problem of this large individual impact. At a level of about 50 divers/4 hrs. (the netting period), the amount of Sagittaria uprooted is about equal to the recovery rate of plots that were experimentally uprooted in winter. Further inspection shows that at a level of 100 divers, the amount of damage, about 0.3 gram/m^2, exceeds the daily recovery rate (about 0.03 gram/m^2/day) by an order of magnitude.

Figure 31 shows another important aspect of diving impact on the Sagittaria community of the Blue Hole. The histogram shows that divers are uprooting smaller and/or younger plants. Recall from the Resistance Experiment that small plants are particularly vulnerable to uprooting due to a shallow root system and the lack of a deep sediment cover. In the Blue Hole, the source of these small, young plants is readily identifiable. They arise from runners which extend from the margins of Sagittaria beds into the open sand areas of the channel and pool.

The type of damage shown in Figure 31, and the amounts shown in Figure 30, indicate that divers are uprooting a very large number of colonizing Sagittaria plants. This suggests that divers, in trampling back the edges of Sagittaria beds, are preventing winter regrowth, and are adding further to the deterioration and loss of Sagittaria cover in the Blue Hole.

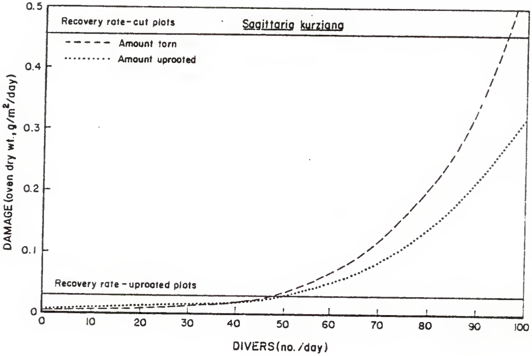


Figure 30. Amounts of Sagittaria torn and uprooted over various levels of diving activity, and the winter recovery rates of plots experimentally subjected to tearing and uprooting. The relationship of damage (y) to number of divers (x) is described by an exponential equation: amount torn, $y = 2.74e^{0.04x}$; amount uprooted, $y = 1.48e^{0.04x}$. The winter recovery rates represent the average growth rate over a 29-day period extending from February 22 to March 21, 1978.

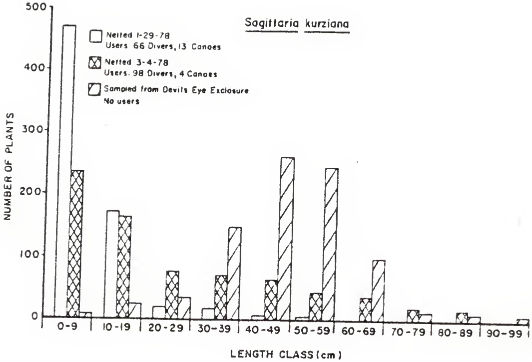


Figure 31. Size distribution of Sagittaria clumps uprooted by divers compared to the size distribution of clumps sampled from the Devil's Eye Exclosure, which receives no use.

To conclude the discussion of diving impact on the Blue Hole in winter, one other important research result will be considered: The exponential pattern of damage shown in Figure 30. The location of the netting site just below the Blue Hole outlet enabled me to simultaneously measure plant damage and observe divers. As the survey progressed over the winter 1977-78, it became apparent that heavy Sagittaria damage occurred on days when the Blue Hole area was congested with scuba divers and snorklers. This congestion almost always occurred around midday (11 a.m. to 2 p.m.) and resulted from: 1. large diving groups (dive class groups and dive clubs with 50 or more individuals regularly visit the Springs) and 2. the concurrent use of the area by many smaller-sized groups (10-15 divers/group were commonly observed).

Jug Spring, with the deep cavern that divers like to explore, can accommodate only a limited amount of use at a given time. On busy days, many scuba divers are forced to wait in the surrounding pool or around the dock area until the Jug has cleared. Some individuals, heedless of the potential for damage, retreat to the edge of the pool where the remaining Sagittaria grows. Others tramp and swim about actively, uprooting and tearing large amounts of plants (some do this whether they are waiting to dive the Jug or not).

An additional problem, which was mentioned in the discussion of summer damage, is the fact that many divers,

arriving at the Blue Hole outlet, choose to walk up the sides of the channel rather than swim against the current.

On quiet days, when smaller and/or fewer groups use the resource, the amount of plant damage decreases considerably as some of the above problems are eliminated. An individual or small diving group can enter the Blue Hole and, without interference, descend the Jug, explore the submerged cavern, and exit from the area. Of course, individual responsibility or lack of it is an important impact factor on both quiet and busy days.

Winter Recovery in the Headsprings Run

The previous section showed that divers tear and uproot large amounts of Sagittaria in the Blue Hole, hastening the deterioration of this area. However, as the following discussion suggests, winter diving does not appear to have much impact on the Headsprings Run, defined as that portion of the river between the Headsprings and the Blue Hole. This does not imply that divers cause no damage, but that the amounts torn and uprooted (Fig. 8) do not exceed the amounts recovered by winter regrowth.

The sections of the Headsprings Run that were mapped in November-December, 1977, and remapped in April, 1978, (Fig. 15) show a considerably gain in plant cover over this four-month period. A review of the results from experimental plots, exclosures, and mapping suggests ways in which this recovery occurred.

Chara recovery. The modest regrowth of Chara in the Second Dock Exclosure (Fig. 22) appears to contradict the suggestion of rapid recovery in map section R (Fig. 15) located just below the Third Dock. Planimetric measurement showed that Chara increased from 1.1 m^2 in July to 2.0 m^2 in October in the Second Dock Exclosure. In map section R, Chara increased from 10 m^2 to 22 m^2 between December and April. The average rate of expansion of the Sëcond Dock bed, relative to the length of edge at the start of mapping, was 37 cm^2/m/day. The average rate of expansion of the Third Dock bed (map section R) was 86 cm^2/m/day.

Although several factors, such as winter leaf fall, current, and depth (which was about the same in both areas) could account for these differences, I believe that the critical factor is the degree of site disturbance. Although map section R was mapped carefully in December, 1977, the substrate was not examined for fragmentary plant remains. When this section was remapped the following September, the substrate was carefully examined and found to contain many small Chara fragments. It appears that growth from fragments, a characteristic of Chara (Tarver 1978), supplemented the lateral outgrowth of the major bed in producing the large cover increase below Third Dock. In contrast, there were virtually no Chara fragments in the thoroughly trampled sand areas of the quadrats surveyed in the Second Dock Exclosure, and lateral outgrowth was the only type of regrowth observed. If due to the absence of fragmentary

remains in the substrate, the slow recovery rate of Chara in the Second Dock Exclosure has important implications for the regrowth of the other areas which have been trampled into a similar condition.

Zizania recovery. The winter recovery of Zizania was fairly extensive in those areas that were mapped in November-December, 1977, and remapped in April, 1978. Two regrowth mechanisms may be responsible for the observed recovery: 1. winter seeding and 2. growth from buried stem fragments.

While netting plants January 14, 1978, I observed a large number of floating Zizania seeds in the drift. The source of these seeds was undoubtedly the fruiting culms of emergent plants which grow upstream along the shallow edges of the Headsprings Run. The mere presence of seeds, however, does not necessarily lead to seedling establishemnt. Sculthorpe (1967) related that Zizania seeds, shed from culms by wind, float for a period of time before they sink. One would intuitively expect that seeds shed along the Run would be rapidly transported downstream before they could sink and germinate. Recall that the results from the Second Dock Exclosure showed only a single instance of Zizania colonization (quadrat 3) that could be ascribed to seeding. At least in that area, seeding did not appear to contribute significantly to the spread of this species in the channel.

A second potential source of Zizania plants is the remains of stem material buried in the substrate. A

Zizania biomass sample showed that this species develops a mat-like layer of stems and roots below the mud surface. Although the above-ground parts of this plant may be completely removed in some areas, inspection of the substrate often shows the fragmentary remains of a root mat. Growth from viable stem fragments embedded in the mat could account for much of the recovery seen in the Run in winter. The results from the experimental *Zizania* plot in the Headsprings Exclosure seem to support this suggestion. Although the above-ground parts of cut plants did not recover, a new seedling, which had grown up in the quadrat, appears to have risen from a buried root mat below.

The recovery of Ludwigia, Nasturtium, Ceratophyllum, and Myriophyllum. The discussion of tuber impact in the Headsprings Reach emphasized that fragile, low-standing-crop species, such as *Ludwigia*, *Nasturtium*, and *Ceratophyllum*, sustain very heavy cover losses in the spring and early summer. By midsummer, these plants have largely disappeared from the trampled channel. They do, however, recover to a degree in winter, as shown in map sections H, Q, and R. A consideration of the growth characteristics of these plants as well as those of *Myriophyllum* shows that they possess mechanisms which enable them to survive in this unstable area. All of these species are able to regenerate from stem and/or leaf fragments (Arber 1920, Sculthorpe 1967, Haslam 1978) and generally exhibit rapid growth rates as shown by this study.

The ability of Myriophyllum and Ceratophyllum to grow from fragments was observed in our work. Fragments of these plants were seen trailing from stakes shortly after they had been driven into the channel floor of the Second Dock Exclosure. One Myriophyllum fragment, which was captured near the base of a stake, secured itself to the underlying substrate by developing numerous adventitious roots along stem nodes. Although Ceratophyllum does not possess roots (Arber 1920), plants of this species were seen growing vigorously while suspended from stakes, fencing, and other submerged obstacles. Rapid growth rates have been measured for both these species. In our study, cut Myriophyllum plots recovered more than 50% of their original above-ground biomass one month after cutting, in both summer and winter plots. Odum (1957) reported winter growth rates as high as 25 dry grams/m^2/day for Ceratophyllum plants growing in a submerged cage at Silver Springs.

Commercial growers of watercress, Nasturtium officinale, have long taken advantage of the regenerative abilities of this plant (Haslam 1978). In addition to rooting at stem nodes (Tarver 1978), this species is able to produce an entire plant from a single detached leaf (Sculthorpe 1967). At the Ichetucknee, the tremendous growth of this plant on the lower fence of the Headsprings Exclosure attests to its powers of propagation and suggests a very rapid growth rate.

In view of these characteristics, it is not surprising that all of these species exhibited some winter recovery (Dec.-April) in the map sections. H, Q, and R (Fig. 15). Note the increase in Ceratophyllum cover in section H and the growth of Nasturtium in section Q. Ludwigia and Myriophyllum recovery is also evident in these map sections.

This discussion of species recovery in winter has described both actual and potential regrowth in the Headsprings Run. This information, however, must be interpreted with caution. Regrowth from stem and/or leaf fragments, whcih is characteristic of Nasturtium, Ludwigia, Ceratophyllum, and Myriophyllum depends on: 1. an upstream source of plant material and 2. the presence of submerged obstacles, sediment deposits, or plant beds which either snag fragments or reduce current locally, enabling colonization. The regrowth of Chara or Zizania, which are able to reproduce from buried stems (or cortical cells in the case of Chara), require a substrate containing viable reproductive parts.

These prerequisites for regeneration, however, appear to be diminishing in the upper reaches of the Ichetucknee River. Park officials have noted that winter regrowth has progresively decreased over the past several years. Also, the map-remap sections represent only a small fraction of the Headsprings Run. In some areas, virtually no recovery was noted over the winter of 1977-78.

The low-standing-crop species, such as Ludwigia, Nasturtium, and Ceratophyllum, may not be able to sustain recovery in the future. It hardly needs to be emphasized that once the upstream sources of these plants are depleted, colonization of the Run from downstream beds would be extremely slow, as it would depend on dispersal agents other than current, such as human or animal transport.

As previously suggested, the winter recovery of Chara and Zizania appears to be dependent on the condition of the substrate. As more areas of the Run become reduced to sterile sand and limerock (Plate 4), which has been the long-term trend in this area, the recovery of these two species will undoubtedly diminish.

Impact of Recreation on the Plant Communities of the Rice Marsh and Floodplain Reach

The results of the summer damage survey showed that, relative to the amount of plant cover, the Headsprings Reach sustains greater plant damage than either the Rice Marsh or Floodplain Reach. Figure 32 extends this analysis further: it shows, for each reach, a Damage Index which is defined as the mean hourly fractional loss per user (the fraction of standing crop that, on the average, is damaged by one user in one hour). An interesting pattern can be seen in this figure; the Damage Index declines by a constant percentage in a downstream fashion from the Headsprings Reach to the middle and lower reaches. The Damage Index of the

Plate 4. Channel erosion in the Second Dock area. All plant material has been trampled out of the substrate, which, in the most extreme case, has been eroded down to limerock.

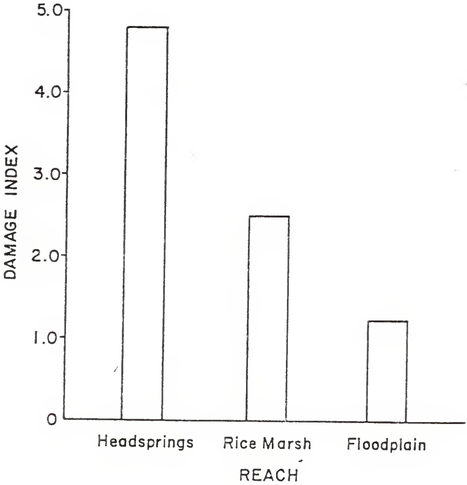


Figure 32. Damage Index for three reaches of the Ichetucknee River. For each reach, Damage Index =

$$\frac{\text{mean plant damage (grams)/hr.} \times 10^7}{\text{standing crop (grams)} \times \text{mean no. of users/hr.}}$$

Headsprings Reach (4.8) is about twice that of the Rice Marsh (2.5), which is twice that of the Floodplain Reach (1.2). The differential impact suggested by the Damage Index is consistent with the observation that recreational activity in the middle and lower reaches does not generally result in the extensive damage that is so evident in the Headsprings Reach. While snorkling the river in October, 1978, I noted very few torn and uprooted beds over the 4-kilometer portion of river bounded by the Rice Marsh and Floodplain.

A number of factors could account for the downstream, exponential decline in the Damage Index. These factors may be roughly classified as environmental or behavioral. Environmental factors would include: water depth, temperature, river width, length of reach, rate of flow, amount of incident light, size of standing crop, amount of cover, and many other variables. Behavioral factors would include such variables as user attitude, user energy, time on river, and tolerance to cold water. Of course, many of these factors are not independent, such as cold tolerance and time on river.

Figure 33 shows the relationship of the Damage Index to variable environmental and behavioral factors. Some factors, which one would intuitively expect to be operative in reducing user impact, do not appear to be related to the Damage Index. Two, for example, are water depth and width. As previously discussed, these factors undoubtedly contribute

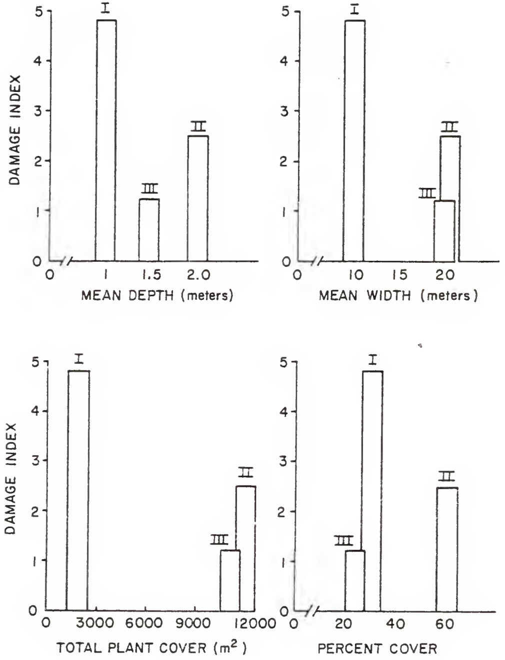


Figure 33. Damage Index related to physical characteristics of the river and behavioral characteristics of use. The velocity of flow in the Rice Marsh (II,---) was estimated as an intermediate value between that of the Floodplain and Headsprings Reach.

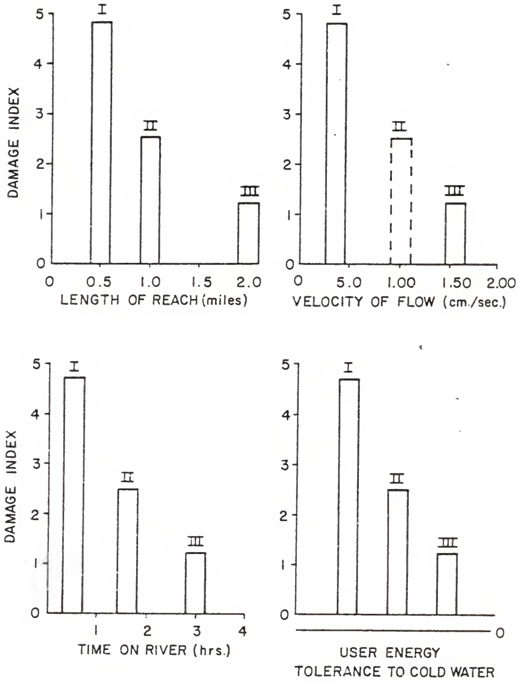


Figure 33. Damage Index related to physical characteristics of the river and behavioral characteristics of use (continued).

to the damage in the narrow and shallow Headsprings Reach. Yet, they should not be considered the sole determinants of recreational impact. The analysis shows that the Damage Index was greater in the deepest and widest reach, the Rice Marsh, than in the shallower, and slightly narrower Floodplain Reach.

Our observations, as well as those of Park personnel, suggest that increasing fatigue and decreasing tolerance to cold water are important in reducing recreational impact in the lower reach of a 5½-kilometer or 3½-mile river. Many tubers, arriving at the Floodplain Reach, appear tired and cold, and generally stay seated on their floats for the remainder of the trip.

This change in the behavior of tubers, who tend to become more passive as they progress downstream, may account for the observed differences in damage to the tributary springs. The heavy damage in the Blue Hole, the first spring downstream of the entry docks, has been described. Mission Springs, about 0.4 kilometers (¼ mile) downstream from Blue Hole, also sustained heavy damage, as large amounts of Sagittaria and Zizania cover were trampled out in summer 1978. In contrast, the major springs downstream from Mission Springs appear to have been only lightly damaged. The Devil's Eye, less than 0.4 kilometers (¼ mile) downstream and on the opposite bank from Mission Springs, showed few signs of disturbance, the only exception being some Sagittaria trampling in the spring run. Similarly, Mill Spring, which

discharges into the Floodplain Reach, showed little evidence of tuber impact.

These differences in damage reflect not only tubers' preferences, in terms of the springs they choose to explore, but also a downstream trend of increasing fatigue and declining curiosity.

Species Damage in the Middle and Lower Reaches

Previous discussion showed that overall plant damage is greater in the Headsprings Reach than in the Rice Marsh or Floodplain Reach when expressed as a fraction of standing crop. In Figure 34, a similar approach is used to compare species damage in the three reaches.

The differences in the magnitude of Sagittaria fractional loss in the upper and lower reaches is striking. Note that in the Headsprings Reach, the fractional loss of Sagittaria exceeds the fractional recovery rate (the fraction of standing crop that can be recovered by regrowth) over most amounts of use. In contrast, the fractional loss of Sagittaria in the middle and lower reaches generally remains below the fractional recovery rate over a wide range of hourly use. These data suggest that in the Rice Marsh and Floodplain Reach, Sagittaria regrowth can generally replace the amounts that are torn and uprooted by recreational use. Considering that Sagittaria accounts for almost 70% of the total cover in the Rice Marsh, it is not

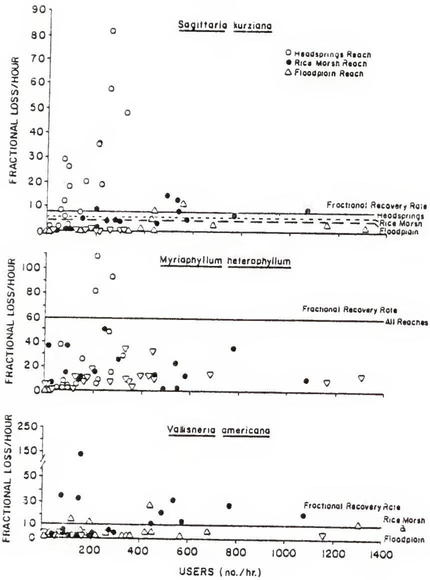


Figure 34. Fractional loss and fractional recovery rate of Sagittaria, Myriophyllum, and Vallisneria.

$$\text{Fractional loss} = \frac{\text{hourly damage (grams)}}{\text{standing crop (grams)}}$$

$$\text{Fractional recovery} = \frac{\text{hourly recovery (grams)}}{\text{standing crop (grams)}}$$

surprising that, on visual inspection, this reach appears to have sustained little damage.

It is misleading however, to assume that recreational use has no impact on the river plants of this area. The damage at the Mission Springs which resulted from tuber trampling this past summer has already been mentioned. Also, data from the plant damage survey suggest that the *Vallisneria* community in this reach may be damaged by summer tubers. Recall from the Results section (Fig. 13) that the amount of *Vallisneria* netted from the Rice Marsh was disproportionately large relative to the size of its standing crop. By weight, *Vallisneria* accounted for about 25% of the plant damage in the Rice Marsh. The standing crop of this species, however, constitutes only 5% of the total standing crop in this reach. As Figure 34 shows, the amounts of *Vallisneria* that are uprooted and torn in the Rice Marsh often exceed the recovery rate of this species. Closer inspection shows that, over amounts of use ranging from 25 to 300 per hour, fractional loss generally remained below the recovery level (on a few hours, however, it exceeded that level by more than an order of magnitude). When amounts of hourly use exceed 300, which is common on weekends, the amount of tearing and uprooting consistently exceeds the amount that is potentially recoverable by regrowth.

The low Damage Index of the Floodplain Reach suggests that the plant communities of this area lose a smaller fraction of their standing crops than do the communities of the

Rice Marsh or Headsprings Reach. Figure 34 shows that, over a wide range of use, the amounts of species damage in this reach do not generally exceed the recovery levels of the respective communities. Note that the amounts of torn and uprooted Myriophyllum, an important community in this reach (35% total cover), remained well below the recovery rate on all 22 netting hours. The figure also shows that Sagittaria (20% total cover) and Vallisneria (10% total cover) damage did not exceed, on most netting hours, the amounts that can be recovered by regrowth.

The only visible signs of damage in the Floodplain Reach occur in the immediate vicinity of the Wayside Park Landing (tuber exit) and on the bluffs at Devil's Den. At Wayside Landing, aquatic vegetation has been eroded by tubers who trample the bottom in exiting the river. This damage is undoubtedly aggravated by heavy day use in this area.

The above discussion compared, for each reach, species damage and recovery during the summer tubing season. In terms of year-round recovery, it needs to be emphasized that, whereas the Headsprings area is subjected to recreational trampling both summer and winter (tubers and divers, respectively), the Rice Marsh and Floodplain Reach remain essentially undisturbed during the winter months. The Sagittaria community in the Headsprings Reach cannot replenish summer losses by winter regrowth, as divers uproot colonizing plants. In the middle and lower reaches, however, the Sagittaria community, as well as other important

communities, has considerable advantage in recouping summer losses due to the long uninterrupted recovery period in winter. Although, for most species, winter production is less than that in summer, the several communities that were tested did show a net biomass accumulation during the coolest months, as has been found for other constant-temperature springs and rivers (Odum 1957, Hannan and Dorris 1970).

Impact of Recreation on the Animals of the River

Mollusks

The results from sampling mollusks were not conclusive. The relatively large numbers and biomass of snails in one of the Headsprings Exclosure samples suggests that protected *Chara* beds may support a more diverse and larger assemblage of snails than disturbed beds. Recall, however, that the number and biomass of snails taken from a badly-torn bed (Third Dock, No. 6) were not very different from the amounts found in less-disturbed areas, excepting the one sample mentioned above. These findings suggest that although snails may be more abundant in healthy, undisturbed beds, they are still able to maintain populations in disturbed areas, even those subject to heavy recreational use. A review of other researchers' findings, as well as our own observations, shows this to be a reasonable assumption.

Whitford (1956), working in several Florida spring systems, found that diatoms, a major food source of grazing river snails, grow abundantly on the stems and leaves of Chara and other aquatic plants. Diatoms, however, are not restricted to this substrate. At the Ichetucknee (Odum's notes 1951) and in other spring-fed rivers (Whitford 1956), these ubiquitous algae have been observed on sand, limerock, and other inorganic substrates. Goniobasis sp. is commonly found on both sand and limerock bottoms, including areas of the Ichetucknee channel, which have been subjected to recreational trampling.

In terms of abundance, one would assume that the large surface area of Chara and other aquatics would support more diatoms, and consequently, more grazing snails, than limerock and sand surface. It is therefore likely that the torn and uprooted plant beds in disturbed areas will support a less than optimal abundance of snails, but will be exploited to a degree by grazing snails.

Arthropods

The results from sampling arthropods, unlike the mollusk results, suggest that the survival of some arthropods may depend on the growth of aquatic plants. A number of studies (Needham 1938, Hynes 1970) have shown that the number and biomass of arthropods found in plant beds are generally much greater than the amounts found in open substrates, such as sand and gravel. Plant shelter appears

to be an important factor for the survival of fresh water shrimp and other organisms which are subject to heavy predation by fish. The results of this study seem to support this suggestion; the sample taken from an area which had lost most of tis plant cover due to trampling sheltered far fewer arthropods, by number and weight, than samples taken from less-disturbed areas with greater cover.

Fish

The fish survey showed that more types and numbers of fish are found in a protected area, the Headsprings Exclosure, than are found in a disturbed area, the channel downstream from the First Dock. This finding likely reflects differences in the availability of food and shelter.

On inspection, it is readily apparent that the channel protected by the exclosure supports a more vigorous and diverse plant growth than does the trampled channel below First Dock. As previously suggested, the loss of cover in disturbed areas may deplete populations of shrimp, crayfish, and other aquatic arthropods which are important components in the diets of many fish (Hynes 1970). The loss of plant cover, however, is detrimental not only by reducing available food: some species appear to be directly dependent on plant shelter, while others, which forage in the open, require shelter for rest periods or for breeding. An example of the former is the pygmy sunfish,

Elassoma evergladei. This fish was often found inside plugs of Chara which were sampled for invertebrates. Pygmy sunfish are rarely observed in the open (Hubbs 1943 , noted the same at Silver Springs), and appear to require a dense growth of plants.

The Carrying Capacity for Recreation

The following discussion summarizes the supporting evidence for the use limits given in Table 6. Because a carrying capacity for recreational use should be defined according to specific objectives, I have recommended several alternatives where more than one management strategy is feasible.

In addition to recommending user limits, I strongly suggest that efforts be made to educate the visiting public about the plant and animal life and the impact of recreational use on this unique and fragile environment. The attitude of the Park visitor is one of the most important impact factors. Education will hopefully foster appreciation and concern, which, combined with use limits, should greatly reduce damage to the springs and river.

Swimmers

Management objective 1. One objective would be to preserve the plant and animal communities of the Ichetucknee River with the stipulation that certain springs, such as

Table 6. Recommended carrying capacities

Use	Management Objective	Recommended Carrying Capacity
Swimming	1. Preserve the plant and animal communities of the Ichetucknee River with the stipulation that certain springs, such as the Headsprings and Blue Hole, be set aside from protection as designated swimming areas.	No limit
	2. Restore plant cover in areas that are badly degraded, including the Headsprings area, Blue Hole, and Wayside Park Landing.	No swimming
Canoeing	1. To maintain present levels of plant cover in the river and springs.	No limit
Diving	1. To permit a slow, gradual recovery of the Blue Hole and other areas disturbed by diving.	12 divers per hour
	2. To restore the Blue Hole and other damaged areas in the shortest time possible by natural recolonization.	No diving
Tubing	1. To maintain a diversity of natural communities and to prevent further deterioration of badly eroded areas.	100 tubers per hour
	2. To permit the recovery, in the shortest time possible, of the springs and eroded river channel in the upper reach of the Ichetucknee.	no tubing in the Headsprings Reach.

the Headsprings and Blue Hole, be set aside from protection as designated swimming areas.

Given the nature of the objective, I do not see a need to place a limit on the number of swimmers.

Swimmers are a minor recreational component at the Ichetucknee Springs, in terms of both numbers and percentage of total use. In winter, less than 15 swimmers per day use the resource. In summer the amount increases, but does not generally constitute more than 15% of total use, or about 150 per day.

Swimming and the trampling that accompanies it appears to have a considerable impact on those areas where it occurs. This activity, however, is generally confined to Headsprings and Blue Hole areas, and does not, therefore, constitute much of a disturbance to the rest of the river.

Management objective 2. A second objective would be to restore plant cover in areas that are badly degraded, including the Headsprings area, Blue Hole, and Wayside Park Landing.

To permit recovery, I recommend that no swimmers be allowed in restoration areas.

Swimmers, by trampling the bottom, tear and uproot large amounts of aquatic plants and disturb invertebrates and nesting fish populations. If plant restoration is attempted, either by planting or allowing present beds to expand,

swimmers will have to be kept out of the area. Several important findings on plant regrowth are pertinent. One is that young and/or small colonizing plants of such species as Sagittaria and Vallisneria, which spread by runners, are easily dislodged. The second is that in badly damaged areas, where the substrate has been trampled clean, regrowth will primarily occur by the lateral outgrowth of plant beds which survive along the edges of such disturbed areas. This type of regrowth, where not aided by buried fragments, is slow. The maximum outgrowth of Sagittaria in the Run Cage in Blue Hole was 60 centimeters over a 3½-month period in summer. The Chara bed in the Second Dock Exclosure expanded, at a maximum, a little over 30 centimeters, or about 12 inches, over a three-month period. Considering the large amount of disturbed bottom in areas such as the Headsprings and Blue Hole, several years will be required for the natural regeneration of cover that has been lost by trampling.

Canoeists

Management objective. A general objective would be to maintain present levels of plant cover in the springs and river.

On the basis of research results and personal observation of canoeing impact, I do not see a need to place restrictions on this activity.

Although the Ichetucknee is a popular canoeing park, the numbers of paddlers, relative to amounts of other types

of users, is small. The maximum number of canoeists observed in our survey was 65 in a four-hour period on a clear January day. A larger number has been recorded, but rarely exceeds 100 per day.

Canoeists generally have little impact on the plant communities of the river and springs. On the busiest day sampled (65 in four hours) only 50 dry grams, or about 1 pound wet weight of plant material was netted. Underwater observation showed that canoes disturb only the surface of plant beds, causing very little breakage and practically no uprooting of submerged plants.

Divers

Management objective 1. One objective, applicable to diving, would be to permit a slow gradual recovery of the Blue Hole and other areas that are disturbed by this activity.

To meet this objective, I recommend that a limit of 12 divers per hour be implemented.

The combined results of the winter plant damage survey and experimental growth plots showed that at a level of 50 divers per four hours, the amount of *Sagittaria* uprooted by divers is about equal to the amount that can be replaced by regrowth. Because diver damage increases exponentially, and because congestion is an important factor in accelerating impact, I recommend that a strict hourly limit be imposed on diving. The figure of 12 per hour assures that there will be no excessive crowding in the Blue Hole and that no

more than 48 divers will use the resource in a given four-hour period.

Although we did not monitor diver damage in the middle and lower reaches of the river (most diving activity is limited to the Headsprings and the Blue Hole areas), I feel that the recommended number, combined with scheduling and registration, would limit some of the types of damage that have been reported from the Rice Marsh and Floodplain Reach. Such activities noted by myself and other observers include:

--digging in both soft and hard substrates (sand, mud, and limerock) in search of marine and terrestrial fossils.

--uprooting aquatics for personal use in aquaria or for the tropical fish trade.

--digging in and around the boils in the river and springs.

Although the recovery rate of Sagittaria is much more rapid in summer than winter (a full order of magnitude in uprooted plots: about 0.03 grams/m^2/day in winter; about 0.3 grams/m^2/day in summer), the suggested limit would permit some recovery during the summer and still provide diving recreation.

Management objective 2. Although the limit that was recommended under objective 1 would permit a gradual recovery, the Department of Natural Resources may want to restore badly-damaged areas in the shortest time possible through natural recolonization.

To achieve this objective, Park management should completely restrict diving in these areas.

The reasons that were given for restricting swimmers from restoration areas apply here also, but more strongly. It has been emphasized that young, colonizing *Sagittaria* plants are easily dislodged from the substrate. During the diver damage survey, we netted a disproportionately large number of small, colonizing plants. Inspection of the Blue Hole area showed that divers were trampling back new growth from the edges of surviving beds.

The recolonization of disturbed areas that have been trampled clean is a relatively slow process. Assuming a maximum rate of lateral outgrowth of about 20 centimeters per month (based on cage growth), at least three years' time will be required for *Sagittaria* to cover about 80% of the channel and pool at Blue Hole (present cover is about 40%). Restricting diving during this recovery period would enable colonizing plants to develop deeper root systems and to accumulate a protective cover of sediment.

Tubing

Management objective 1. One objective for managing tuber recreation would be to maintain the present diversity of plant and animal life and to prevent the further deterioration of badly-eroded areas.

To achieve this objective, I recommend a limit of 100 tubers per hour.

Damage in the Headsprings Reach is about twice that in the Rice Marsh and about four times that in the Floodplain. I strongly suggest that the carrying capacity be based on that level of use at which the most vulnerable communities, those of the Headsprings Reach, can recover by natural regrowth the material that is damaged by tubing. Limiting tuber use on this basis should assure the protection of all plant communities on a spring-wide basis, and additionally, maintain diverse habitats for breeding animal populations.

A review of the data from the plant damage survey, experimental growth plots, and other related research suggests that when amounts of hourly tubing exceed 100, the damage caused by trampling, jumping, and pulling is significantly greater than the amount that can be recovered hourly. The species which appear to be most vulnerable possess weak stems and shallow root systems. These include, in fact, most of the plant species in the river and springs, but particularly *Chara*, *Myriophyllum*, *Ludwigia*, *Nasturtium*, and *Ceratophyllum*. Of the plants listed above, three, *Ludwigia*, *Nasturtium*, and *Ceratophyllum*, are found in small amounts in both the Headsprings Reach and the lower reaches. This feature, combined with their fragility, considerably accentuates the impact of tubing on these communities. The trampling that accompanies heavy use results in large losses of cover; the loss of *Ceratophyllum* cover was estimated to

be as high as 8%, and that of *Ludwigia* and *Nasturtium* about 2% on busy weekend days when hourly amounts of tubing consistently exceed 100.

Although these three species showed some winter recovery, there are many areas of the Headsprings Reach, especially those which have been thoroughly trampled, that exhibited very little regrowth.

The amounts of *Sagittaria*, *Zizania*, and *Chara* that are damaged by tubers do not constitute as large a percentage loss, but do, however, lead to serious degradation of these communities. Our data on *Chara* damage and *Zizania* recovery are not adequate for analysis, but we do have good information on both the recovery rates and damage rates of *Sagittaria*. If the amounts of *Sagittaria* damage are averaged over various ranges of use, 0-100, 100-200 tubers per hour, etc., one finds that in the range of 0-100 tubers per hour, about 75% of the damage can be recovered by hourly regrowth; in the 100-200 range, about 66% of the damage can be recovered; and in the 200-300 range, only 20% of the damaged material can be recovered. I feel that the 75% recovery level is the maximum that can be sustained without causing further deterioration of this community. Winter regrowth should be able to restore the *Sagittaria* that is damaged in summer under the sustained use of 0-100 tubers per hour.

Perhaps the strongest support for the limit I have recommended comes from the data of June 14, a quiet weekday when amounts of hourly tubing remained below 100 for five of six collecting hours (the amount for the second hour was 136). The material that was netted over six hours weighed about 210 grams, which is about equal to the average hourly amount that was netted on Saturday, May 21, when levels of tubing activity ranged around 200 per hour for five of six collecting hours (76 tubers were recorded for the last hour). On June 14, hourly *Sagittaria* damage exceeded the hourly recovery rate on only one of the six netting hours, and that was by less than a factor of two. On May 21, the hourly amounts of *Sagittaria* damage were greater than the recovery rate during all hours of collection, and, in fact, exceeded that level by a factor of eight on the busiest hour (268 tubers).

We also noticed on June 14 that the water remained fairly clear over most of the netting hours; on busier days, the water is nearly opaque with sediment stirred by tubers. The deposition of this sediment on plant surfaces, which is so conspicuously evident in the *Sagittaria* beds of the Blue Hole pool, undoubtedly diminishes the amount of light that reaches photosynthetic tissue. I believe that limiting tuber use to 100 per hour will not only result in healthier plant beds, but will also provide a more satisfactory experience for the user.

<u>Management objective 2</u>. A second objective, one which I think should be given serious consideration, would permit the recovery, in the shortest time possible, of the upper reaches of the river.

It would be necessary to restrict tubing from the Headsprings Reach to achieve this objective.

The upper reaches of the river, including the Headsprings, Blue Hole, and Mission Springs, have lost large amounts of plant cover and are badly eroded. To permit the natural recovery of these areas I suggest that: 1. no tubing be allowed in this area and 2. that the fenced exclosure below the Headsprings be retained indefinitely as an upstream source of plants for downstream recolonization (I recommend the continuation of this exclosure under any management plan).

One solution to the recommended restriction would be to move the entry point for tubers downstream to a wider and deeper launching spot. One should not anticipate, however, that a wider and deeper entry area could sustain more than 100 tubers per hour, as recommended under management objective 1.

Analysis of the damage survey data showed that tuber impact is not directly related to such morphological characteristics as river width and depth. It appears that user behavior, which changes markedly over the course of the river, may be a more important factor. The impact of

excessive trampling and destructive fooling which is so prevalent in the Headsprings area, is undoubtedly intensified by the shallowness and narrowness of this reach. Deeper water and greater widths, however, do not necessarily reduce tubing impact, but may serve only to direct it to shallow shoals and to the edge of the channel. This aspect of tuber impact is amply demonstrated in the Blue Hole, where strong flow and deep water in the center of the channel discourage most tubers from swimming or paddling up the run. Instead, they head to the edge and tramp out the banks and plant beds there, leaving the growth in the center intact.

Similarly, the shoals, shallows, and springs of the downstream reaches could well be subject to the severe trampling that has led to the deterioration of the Headsprings Run and Blue Hole.

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APPENDIX A-1
PERCENTAGE DRYWEIGHT OF NETTED PLANTS,
PALNT DAMAGE SURVEY, SUMMER 1978

Netted plants were sorted by reach, species, and type of damage (leaf fragment or uprooted clump) then drained on screens (one hour) and weighed. For each category, subsamples of drained plants were oven-dried (70°C) to constant temperature. If there were no significant (5%) differences between reaches, a mean for all subsamples of a species and damage type was determined.

Species	Reach	Number of Subsamples	Mean Dry Weight (% of f.w.)[a]
Sagittaria kurziana			
leaf fragments	H.S., R.M., F.P.[b]	14	8.7 ± 1.4[c]
uprooted clumps	H.S.	8	9.3 ± 0.9
	R.M.	5	11.1 ± 1.0
	F.P.	6	9.5 ± 2.2
Zizania aquatica			
leaf fragments	H.S., R.M., F.P.	10	8.1 ± 1.4
uprooted clumps	H.S.	4	10.0 ± 0.9
	F.P.	4	15.7 ± 2.6
Vallisneria americana			
leaf fragments	R.M., F.P.	12	8.9 ± 1.3
uprooted clumps	R.M., F.P.	12	10.9 ± 2.1
Chara sp.	H.S.	5	17.9 ± 2.0
	F.P.	6	15.0 ± 1.4
Myriophyllum heterophyllum	H.S.	5	15.2 ± 1.5
	R.M.	5	10.2 ± 0.6
	F.P.	10	9.6 ± 0.6
Ludwigia repens	H.S., R.M., F.P.	7	13.7 ± 3.3
Ceratophyllum demersum	H.S., R.M., F.P.	1	12.9
Nasturtium officinale	H.S., R.M., F.P.	4	7.0 ± 1.5

APPENDIX A-1
(Continued)

Species	Reach	Number of Subsamples	Mean Dry Weight (% of f.w.)[a]
Pistia stratoites	F.P.	5	6.4 ± 0.3
Cicuta maculata	H.S., R.M., F.P.	5	5.7 ± 0.2
Fontinalis sp.	H.S., R.M., F.P.	5	14.9 ± 1.1

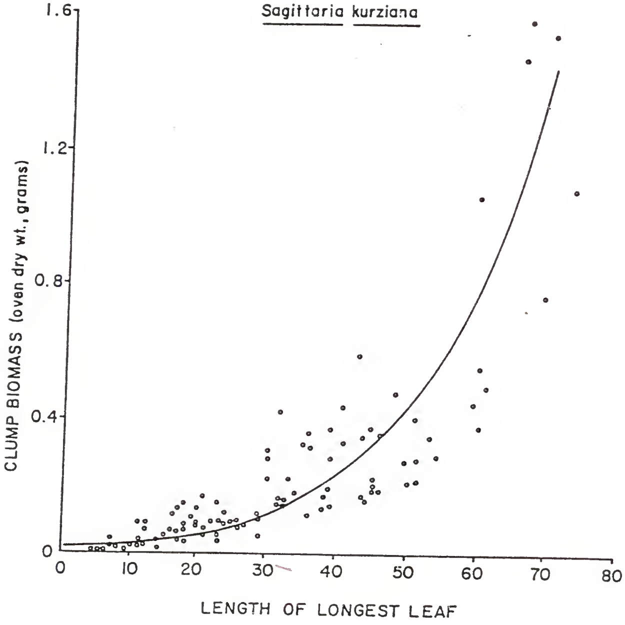
[a]f.w. = freshweight.

[b]H.S. = Headsprings Reach, R.M. = Rice March, F.P. = Floodplain Reach

[c]Standard deviation.

APPENDIX A-2

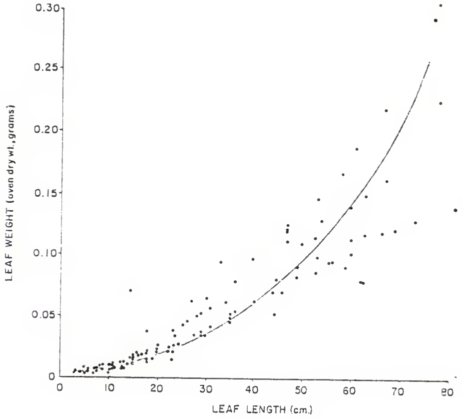
RELATIONSHIP OF CLUMP BIOMASS AND LENGTH OF LONGEST LEAF, *Sagittaria kurziana*



The relationship of weight in grams (y) to longest leaf length in centimeters (x) is described by an exponential equation: $y = 0.02e^{0.06x}$ ($r^2 = 0.79$). This equation was used to estimate clump recovery (biomass) in uprooted plots where harvesting was not possible.

APPENDIX A-3

RELATIONSHIP OF LEAF WEIGHT
AND LEAF LENGTH, *Sagittaria kurziana*



The relationship of weight in grams (y) to length in centimeters (x) is described by an exponential equation: $y = 0.004e^{0.06x}$ ($r^2 = 0.81$). This equation was used to estimate leaf recovery (biomass) in cut plots where harvesting was not possible.

APPENDIX A-4
INDIRECT AND DIRECT MEASUREMENT OF PLANT BIOMASS IN EXPERIMENTAL PLOTS

Species	Treatment	Field Measurement of Biomass Recovery	Conversion Factor
Indirect			
Sagittaria	clumps uprooted from substrate[a]	length of longest leaf in a clump	Biomass of clump (g) = $0.02e^{0.06}$ leaf length cm.
	leaves cut 2.5 cm. above substrate	length of leaf	Biomass of leaf (g) = $0.004e^{0.06}$ leaf length cm.
Direct			
Chara	cut back to substrate level	above ground materials harvested	
Myriophyllum	stems cut at substrate level	stems harvested	
Vallisneria	leaves cut 2.5 cm. above substrate	leaves harvested	
	clumps uprooted from substrate	clumps harvested	
Zizania	leaves cut 2.5 cm. above substrate	leaves harvested	
	clumps uprooted from substrate	clumps harvested	

[a]The initial and final biomass of *Sagittaria* experimental plots was determined by weighing harvest; the biomass of intermediate stages of recovery was determined by indirect measurement.

APPENDIX B

AMOUNTS OF HOURLY USE AND DAMAGE, BY SPECIES
PLANT DAMAGE SURVEY, SUMMER, 1978

Survey Date and Hour	No. of Users	Sagittaria uprooted	Sagittaria torn	Zizania uprooted	Zizania torn	Myrio-phyllum	Chara	Cicuta	Lud-wigia	Nast-urtium	Cerato-phyllum	Moss	Total
SPECIES DAMAGE - HEADSPRINGS REACH (oven dry wt., g)													
22 April													
8:45- 9:45	63	11.9	27.9	0.0	10.7	7.1	1.5	2.2	0.5	2.0	1.0	+	64.8
9:45-10:45	68	27.5	68.3	0.0	9.4	1.5	6.6	2.6	3.9	0.8	0.8	+	121.4
10:45-11:45	154	10.7	54.8	8.9	24.7	5.0	0.0	129.2	4.7	8.9	3.7	+	250.6
11:45-12:45	323	26.0	85.1	3.0	50.5	5.5	0.3	55.4	15.8	12.0	17.6	+	271.2
Total	608	76.1	236.1	11.9	95.3	19.1	8.4	189.4	24.9	23.7	23.1	+	708.0
Percent		10.7	33.3	1.7	13.5	2.7	1.2	26.7	3.5	3.3	3.3	+	99.9
21 May													
10-11	226	19.2	23.7	0.0	15.3	1.6	+[a]	6.5	3.6	1.4	+	1.2	72.5
11-12 Noon	268	73.5	98.3	13.4	66.1	2.8	19.5	1.9	28.0	+	2.5	+	406.0
12- 1	260	108.6	84.6	0.0	37.5	9.3	+	2.8	8.6	+	+	+	251.4
1- 2	211	47.6	67.0	4.3	53.8	20.9	+	16.4	8.9	+	2.1	+	221.0
2- 3	211	31.5	85.2	29.0	158.7	1.0	+	3.6	24.6	+	+	5.9	239.6
3- 4	76	49.4	38.3	17.2	18.8	0.8	+	8.3	9.2	26.5	0.7	+	169.2
Total	1252	429.8	397.1	63.9	250.2	36.5	19.5	39.5	82.9	27.9	5.3	7.1	1359.7
Percent		31.6	29.2	4.7	18.4	2.7	1.4	2.9	6.1	2.1	0.4	0.5	100.0

APPENDIX B
(Continued)

Survey Date and Hour	No. of Users	Sagittaria uprooted	Sagittaria torn	Zizania uprooted	Zizania torn	Myriophyllum	Chara	Cicuta	Ludwigia	Nasturtium	Ceratophyllum	Moss	Total
14 June													
10-11	88	18.5	40.2	8.7	13.8	0.5	+	+	0.4	+	+	+	82.1
11-12 Noon	136	18.7	8.0	+	9.4	1.1	+	0.7	1.9	0.4	+	+	40.2
12- 1	59	21.2	6.1	+	4.8	+	+	0.9	+	+	+	+	33.0
1- 2	84	3.5	5.5	+	1.6	0.6	+	+	+	0.1	+	+	11.3
2- 3	69	5.4	15.3	+	5.2	0.3	+	+	4.9	+	+	+	31.1
3- 4	47	4.9	2.1	+	3.2	0.3	+	+	+	+	+	+	15.2
Total	484	72.2	77.2	13.4	38.0	2.8	0.0	1.6	7.2	0.5	+	+	212.9
Percent		33.9	36.3	6.3	17.8	1.3	0.0	0.8	3.4	0.2	+	+	100
9 July													
9-10	179	60.6	38.6	+	4.2	0.4	5.7	8.3	.1	0.2	+	+	118.1
10-11	438	34.3	63.7	2.0	21.0	3.1	21.2	4.4	2.5	9.7	2.4	+	167.3
11-12 Noon	733	92.6	124.5	11.8	47.8	8.8	19.6	988.4	5.0	1.1	0.4	+	1300.3
12- 1	541[b]	70.3	69.0	6.4	16.4	2.7	20.2	55.3	2.5	0.7	0.6	+	244.1
1- 2	500	58.4	103.6	6.3	23.4	15.4	19.9	8.6	1.2	0.4	+	+	237.2
2- 3	400	84.7	109.1	11.4	7.5	3.1	1.6	9.3	3.8	0.5	+	+	231
3- 4	60	19.6	12.1	18.4	26.4	0.5	17.6		4.9		3.4	+	102.9
Total	2851	420.5	520.6	56.3	146.7	34.0	105.8	1077.3	20.0	12.6	6.8	+	2400.6
Percent		17.5	21.7	2.3	6.1	1.4	4.4	44.9	0.8	0.5	0.3	+	99.9

APPENDIX B
(Continued)

Survey Date and Hour	No. of Users	Sagittaria uprooted	Sagittaria torn	Zizania uprooted	Zizania torn	Myrio-phyllum	Chara	Cicuta	Lud-wigia	Nast-urtium	Cerato-phyllum	Moss	Total
5 August													
9-10	172	3.6	50.5	+	0.5	2.1	1.5	3.6	1.3	+	+	+	63.1
10-11	547	18.2	43.2	+	6.1	3.6	9.9	9.2	1.4	+	+	+	91.6
11-12 Noon	943	35.5	106.8	35.0	13.8	14.2	156.4	8.8	2.6	4.3	+	+	377.4
12- 1	904	37.8	159.4	16.4	22.5	20.3	130.4	9.9	3.6	0.9	2.0	+	403.2
1- 2	248	13.8	38.1	8.6	4.6	2.5	20.5	2.0	+	+	1.2	+	91.3
2- 3	35	2.4	4.8	6.9	4.7	0.7	14.2	+	+	0.9	+	+	34.6
3- 4	15	5.0	11.4	3.5	+	0.0	332.9	0.0	2.5	+	+	+	22.4
Total	2864	116.3	414.2	70.4	52.2	43.4	332.9	33.5	11.4	6.1	3.2	+	1083.6
Percent		10.7	38.2	6.5	4.8	4.0	30.7	3.1	1.1	0.6	0.3	+	100.0
Grand Total	8059	1114.9	1645.2	2.5.9	582.4	135.8	466.6	1341.3	146.4	70.8	38.4	7.1	5764.8
Percent		19.3	28.5	3.7	10.1	2.4	8.1	23.3	2.5	1.2	0.7	0.1	
		47.8		13.8									

a. + indicates that some material was netted, but a very small quantity.
b. estimated value, tally was cleared before recorded.

APPENDIX B
(Continued)

Survey Date and Hour	No. of Users	Sagittaria uprooted	Sagittaria torn	Zizania uprooted	Zizania torn	Myrio-phyllum	Chara	Cicuta	Lud-wigia	Cerato-phyllum	Vallisneria uprooted	Vallisneria torn	Total
SPECIES DAMAGE - RICE MARSH (oven dry wt., g)													
21 May													
10-11	146	55.0	47.4	0.5	7.7	21.3	+	+	0.4	+	+	3.7	141.0
11-12 Noon	241	265.4	39.2	30.6	11.1	100.1	+	28.1	0.5	+	+	7.4	482.4
12- 1	298	94.0	241.5	29.0	1.3	49.3	0.1	+	+	+	22.1	10.3	447.6
1- 2	274	266.1[c]	79.7	0.1	18.6	183.5	+	6.6	0.7	8.6	19.8	20.5	604.2
2- 3	223	mv	mv	mv	mv	mv	mv	mv	mv	mv	mv	mv	mv
3- 4	202	112.1	50.4	3.7	22.6	160.4	+	37.4	18.2	2.8	+	20.9	428.5
Total	1384	792.6	458.2	63.9	61.3	514.6	0.1	72.1	19.8	11.4	41.9	67.8	2103.7
Percent		37.7	21.8	3.0	2.9	24.5	+	3.4	1.0	0.5	2.0	3.2	100
14 June													
10-11	8	18.5	35.5	+	2.1	73.0	+	+	+	+	44.9	7.1	181.1
11-12 Noon	79	19.2	20.0	1.2	+	7.3	66.8	+	+	0.4	776.6	152.4	1043.9
12- 1	154	115.4	49.2	4.9	7.8	14.2	+	11.3	+	+	+	16.7	219.5
1- 2	84	35.9	60.0	+	12.7	30.2	+	20.3	+	+	24.6	19.6	203.3
2- 3	83	171.7	107.7	9.2	3.0	73.0	+	0.1	+	+	+	13.2	317.9
Total	408	300.7	272.4	15.3	25.6	197.7	66.8	31.7	+	0.4	846.1	209.0	1965.7
Percent		15.3	13.9	0.8	1.3	10.1	3.4	1.6	+	+	43.0	10.6	100

APPENDIX B
(Continued)

Survey Date and Hour	No. of Users	Sagittaria uprooted	Sagittaria torn	Zizania uprooted	Zizania torn	Myrio-phyllum	Chara	Cicuta	Lud-wigia	Cerato-phyllum	Vallisneria uprooted	Vallisneria torn	Total
9 July													
10-11	200	617.1	77.7	+	11.7	30.0	1.1	+	+	+	2.6	12.3	752.5
11-12 Noon	449	236.0	69.0	42.0	8.2	25.3	0.1	12.9	0.2	+	39.0	28.0	460.7
12- 1	575	305.9	93.5	188.8	26.2	24.5	0.1	1.8	+	+	47.1	30.0	717.9
1- 2	534	757.2	195.6	199.3	53.2	44.1	1.2	+	+	+	58.9	60.2	1369.7
2- 3	488	802.9	128.1	3.5	21.7	0.1	9.7	16.2	+	+	87.1	35.7	1105.0
Total	2246	2719.1	563.9	433.6	121.0	124.0	12.2	30.9	0.2	+	234.7	166.2	4405.8
Percent		61.7	12.8	9.8	2.7	2.8	0.3	0.7	+	+	5.3	3.8	99.9
5 August													
10:30-11	168	56.0	18.8	2.0	0.1	5.5	+	11.2	+	+	5.8	5.2	104.6
11 -12 Noon	541	511.3	98.0	89.0	21.5	5.8	+	+	0.1	+	1097.0	55.8	1878.5
12 - 1	1078	529.9	118.8	219.3	15.2	18.5	+	+	15.0	13.0	79.7	35.4	1044.8
1 - 2	769	376.9	120.3	13.9	18.7	70.0	+	6.0	2.3	+	128.7	26.5	763.3
2 - 3	147	223.3	94.9	35.6	8.9	17.6	+	5.1	3.7	+	159.5	24.7	573.3
3 - 4	28	14.6	18.3	75.2	+	14.7	+	+	+	+	78.2	4.7	206.7
Total	2731	1712.0	469.1	435.0	64.4	132.1	+	22.3	21.1	13.0	1548.9	153.3	4571.2
Percent		37.4	10.3	9.5	1.4	2.9	+	0.5	0.5	0.3	33.9	3.4	100.1
Grand Total	6769	5524.4	1763.6	947.2	272.3	968.4	79.1	157.0	61.6	24.8	2671.6	596.3	13066.1
Percent		42.3	13.5	7.2	2.1	7.4	+	1.2	0.5	0.2	20.4	4.6	
		55.8		9.3							25.0		

c. mv indicates a missing value.

APPENDIX B
(Continued)

Survey Date and Hour	No. of Users	Sagittaria uprooted/torn		Zizania uprooted/torn		Myrio- phyllum	Chara	Cicuta	Pistia	Moss	Vallisneria uprooted/torn		Total
SPECIES DAMAGE - FLOODPLAIN REACH (oven dry wt., g)													
21 May													
9:30-10	7	+	+	+	0.1	76.5	5.5	+	9.7	3.5	+	3.3	98.6
10 -11	13	+	1.0	+	+	38.6	1.5	0.3	+	11.0	+	1.1	53.5
11 -12 Noon	174	2.4	3.2	+	+	122.8	80.5	0.4	24.3	6.2	+	3.1	242.9
12 - 1	329	+	10.7	+	0.2	409.1	5.4	218.1	7.6	0.6	2.8	12.4	666.9
1 - 2	397	43.5	7.3	+	+	142.8	13.7	+	172.6	+	+	1.3	381.2
2 - 3	431	129.2	42.2	17.2	9.3	126.4	24.2	127.2	149.5	2.4	37.9	7.3	672.8
3 - 4	340	5.1	8.0	+	+	110.5	5.3	0.9	14.1	16.0	+	2.1	162.0
4 - 5	353	13.9	1.7	+	+	31.8	+	100.6	14.2	+	+	2.1	164.3
5 - 5:30	mv.	7.5	11.2	1.0	1.4	46.2	+	210.1	10.7	+	5.6	5.4	299.1
Total	2044	201.6	85.3	18.2	11.0	1104.7	136.1	657.6	402.7	39.7	46.3	38.1	2741.3
Percent		7.4	3.1	0.7	0.4	40.3	5.0	24.0	14.7	1.4	1.7	1.4	100.1
14 June													
9-10	2	15.3	0.2	+	+	42.2	18.1	+	13.0	2.1	+	0.4	91.3
10-11	6	+	0.5	+	+	22.3	14.3	+	82.3	+	+	0.1	119.5
11-12 Noon	38	+	+	+	+	29.2	4.7	+	103.5	+	+	+	137.4
12- 1	169	5.4	3.1	+	+	101.5	14.7	+	37.6	+	+	5.7	168.0
1- 2	344	+	1.1	11.7	+	91.2	9.1	+	50.9	9.3	17.2	0.5	191.0
2- 3	121	15.3	0.5	+	+	17.0	1.5	+	37.5	+	110.3	24.3	206.4
3- 4	130	17.4	2.8	+	+	142.9	0.3	+	27.1	8.3	+	2.5	201.3
Total	810	53.4	8.2	11.7	+	446.3	62.7	+	351.9	19.7	127.5	33.5	1114.9
Percent		4.8	0.7	1.0	+	40.0	5.6	+	31.6	1.8	11.4	3.0	99.9

APPENDIX B
(Continued)

Survey Date and Hour	No. of Users	Sagittaria uprooted	Sagittaria torn	Zizania uprooted	Zizania torn	Myrio-phyllum	Chara	Cicuta	Pistia	Moss	Vallisneria uprooted	Vallisneria torn	Total
9 July													
9-10	2	6.1	3.4	+	+	60.9	2.4	+	+	5.8	0.2	0.6	79.4
10-11	203	43.3	11.9	+	+	1.1	22.7	+	+	2.9	26.0	10.7	118.6
11-12 Noon	227	10.4	8.6	+	+	192.4	23.1	+	1.4	9.7	106.5	11.1	363.2
12- 1	540	245.9	76.8	57.5	1.1	406.4	39.0	1.1	3.4	1.3	31.6	8.7	872.8
1- 2	713	429.9	2.2	+	11.0	132.3	153.4	+	+	4.3	+	1.4	734.5
2- 2:30	371	0.6	2.7	+	+	93.3	9.0	+	13.1	4.8	24.5	6.2	154.2
Total	2056	736.2	105.6	57.5	12.1	886.4	249.6	1.1	17.9	28.8	188.8	38.7	2322.7
Percent		31.7	4.5	2.5	0.5	38.2	10.7	+	0.8	1.2	8.1	1.7	99.9
5 August													
9-10	20	+	+	5.8	0.4	35.6	+	+	+	+	+	+	41.8
10-11	81	+	+	+	1.7	68.4	12.5	1.2	+	+	28.6	3.8	116.2
11-12 Noon	225	+	2.9	+	+	119.3	14.8	0.3	+	+	+	4.7	142.0
12- 1	681	124.1	+	+	+	180.7	35.9	74.8	18.1	3.2	19.8	18.6	475.2
1- 2	1308	30.1	1.4	+	+	171.7	10.2	+	40.0	1.1	88.4	8.2	351.1
2- 3	1162	122.8	9.4	+	+	113.5	14.4	604.9	22.3	4.8	17.2	8.3	918.3
3- 4	447	8.4	3.0	+	+	122.7	33.2	124.1	70.5	2.9	218.6	6.3	589.7
Total	2765	285.4	16.7	5.8	2.8	811.9	121.0	805.3	150.9	12.0	372.6	49.9	2634.3
Percent		10.8	0.6	0.2	0.1	30.8	4.6	30.6	5.7	0.5	14.1	1.9	99.9
Grand Total	9719	1276.6	112.9	93.2	25.9	3249.3	569.4	1464.0	923.4	100.2	735.2	160.2	8813.2
Percent		14.5	1.3	1.1	0.3	36.9	6.5	16.6	10.5	1.1	8.3	1.8	
		15.8		1.4							10.1		

APPENDIX C
BIOMASS OF AQUATIC PLANTS OF THE ICHETUCKNEE RIVER

The subheadings under species names indicate that portion of the plant which was sampled. Where more than one sample was obtained, the table lists mean dry weight and standard deviation.

Species	Date Sampled	Number of Samples	Sample Size (m^2)	Mean Dry Weight (g/m^2)
Sagittaria kurziana				
Leaves	2-20-28	7	0.125	503.2 ± 63.5
	6-18-78	3	0.125	692.0 ± 81.6
Leaves, Stems and Roots	2-20-78	3	0.125	536.8 ± 81.6
	6-18-78	3	0.125	1001.6 ± 92.0
Zizania aquatica submerged				
Leaves	10-12-78	2	0.25	59.6 ± 40.2
Leaves, Stems and Roots	10-12-78	1	0.25	186.2 ± 86.1
Zizania aquatica emergent				
Leaves, Stems and Roots	10-12-78	1	0.25	568.8
Cicuta maculata floating mat				
Leaves, Stems and Roots	10-12-78	1	0.25	662.0
Ceratophyllum demersum				
Leaves and stems[a]	10-12-78	2	0.0625	67.2 ± 18.1
Chara sp. Above ground	2-25-78	2	0.625	961.6 ± 244.8
	7- 7-78	2	0.625	996.8 ± 18.4

APPENDIX C
(Continued)

Species	Date Sampled	Number of Samples	Sample Size (m^2)	Mean Dry Weight (g/m^2)
Ludwigia repens				
Above ground	2-18-78	3	0.125	76.8 ± 37.5
Myriophyllum heterophyllum				
Above ground	2-22-78	2	0.125	169.6 ± 18.6
	7- 7-78	2	0.125	293.6 ± 17.6
Nasturtium officinale				
Leaves, Stems and Roots	10-12-78	2	0.0625	99.2 ± 13.6
Vallisneria americana				
Leaves	8-15-78	1	0.250	464.8
Leaves, Stems and Roots	8-15-78	1	0.250	688.8

[a]Ceratophyllum demersum does not possess roots.

APPENDIX D
STANDING CROP OF AQUATIC PLANTS IN THREE REACHES OF THE ICHETUCKNEE RIVER

Standing crop values were obtained by multiplying mean biomass (g/m^2) times cover value (m^2), which was determined by planimetry of the aquatic plant communities map (Fig. 6).

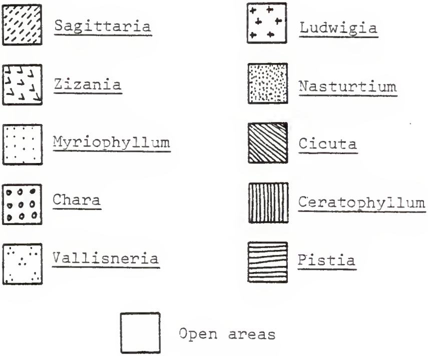
Species	Headsprings Reach		Rice Marsh		Floodplain Reach	
	Cover[a] (m^2)	St. Crop (Kg)	Cover (m^2)	St. Crop (Kg)	Cover (m^2)	St. Crop (Kg)
Sagittaria kurziana	622	623[1]	7066	7080	2475	2477
Chara sp.	369	368	1977	1971	3479	3469
Zizania aquatica	450	284	2152	400	61	11
Myriophyllum heterophyllum	66	19	660	194	4190	1232
Vallisneria americana	0	0	807	556	1231	848
Ludwigia repens	57	4	10	1	20	1.5
Nasturtium officinale	39	4	13	1	23	2.3
Ceratophyllum demersum	19	1	+[b]	+	+	+
Cicuta maculata	230	152	+	+	+	+
Fontinalis sp.	+	+	+	+	+	+
Total Cover or Standing Crop	1,872	1,455	12,685	10,203	11,479	8,041
Unvegetated Area (m^2)	4,228		8,415		40,721	
Total Area of Reach (m^2)	6,100		21,100		52,200	

[a]Cover was measured in winter. Summer values, particularly in the heavily trampled Headsprings Reach, would be less.

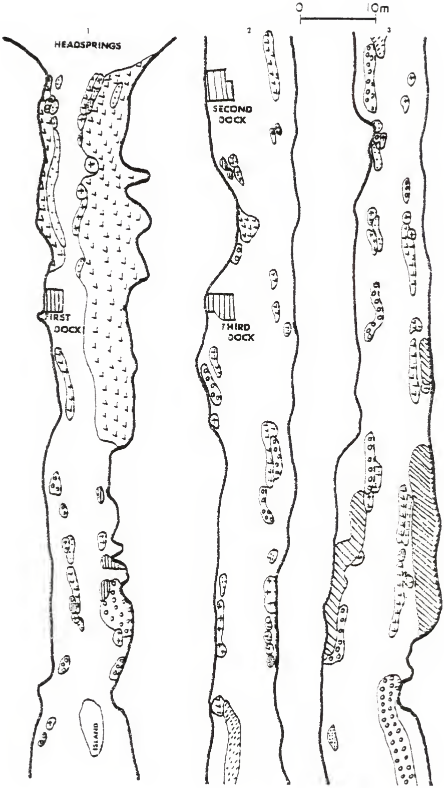
[b]+ indicates that a species is present, but its area/cover not measured.

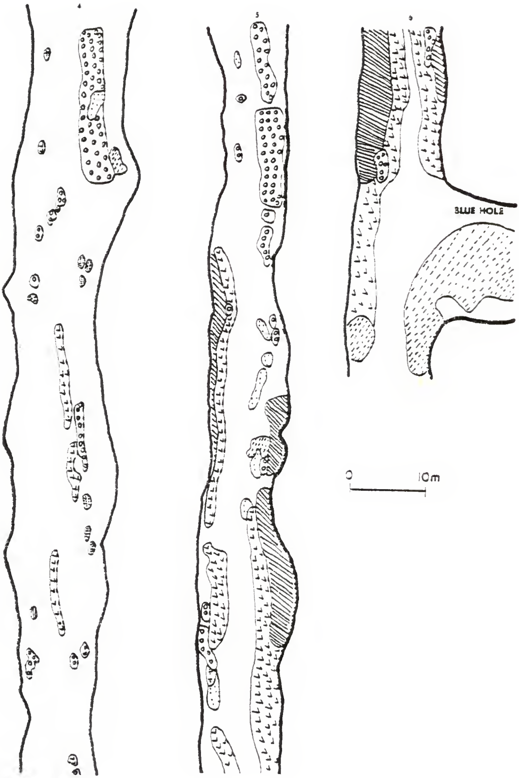
APPENDIX E
PLANT COMMUNITIES OF THE ICHETUCKNEE RIVER

KEY

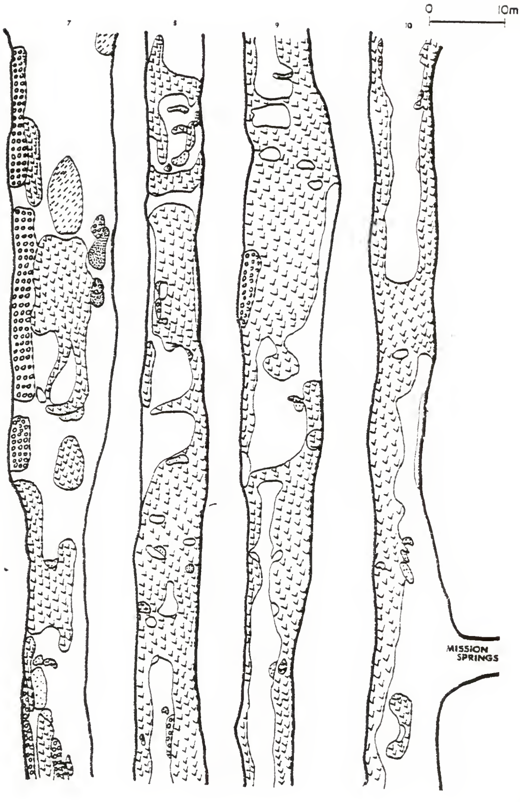


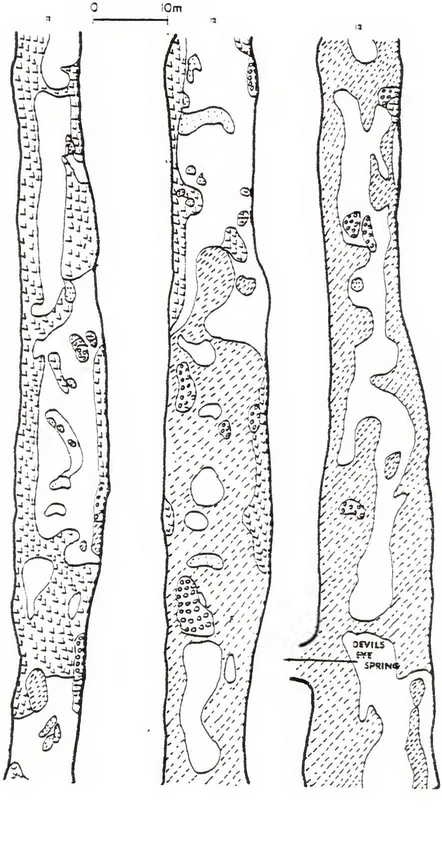
The maps show the major plant beds in three reaches of the Ichetucknee River. Both submerged and emergent beds of aquatic plants are included in the map of the Headsprings Reach. Only submerged beds are shown for the Rice Marsh and Floodplain Reach. The Headsprings Reach and Rice Marsh are subdivided into 100-meter sections, the Floodplain Reach into 80-meter sections. The sections are numbered consecutively with the upstream end at the top of the page. Certain features, such as docks, landings, and springs, are indicated to provide location references. In evaluating long-term cover changes, it is important to understand that: 1. the plant beds shift position under natural forces (meandering of channel and flooding) as well as recreational trampling, and 2. there is a margin of error, estimated to be about 10%, in both the position and size of the beds shown in the maps.

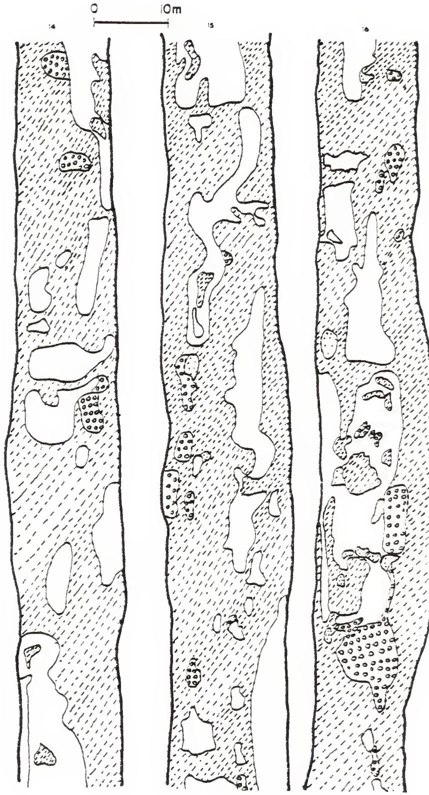

0
10m
1
HEADSPRINGS
FIRST
DOCK
ISLAND
2
SECOND
DOCK
THIRD
DOCK
3

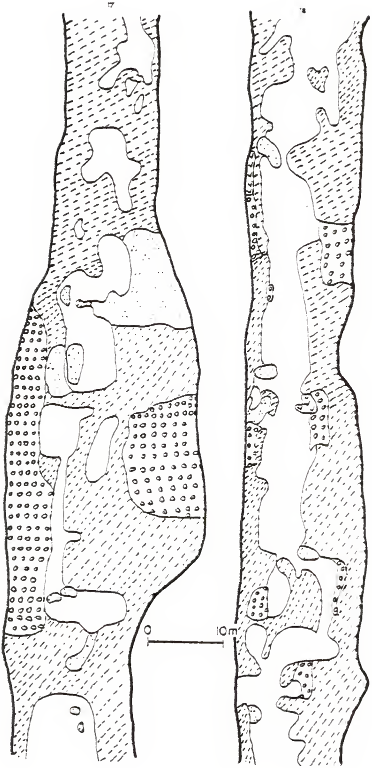

BLUE HOLE
0
10m

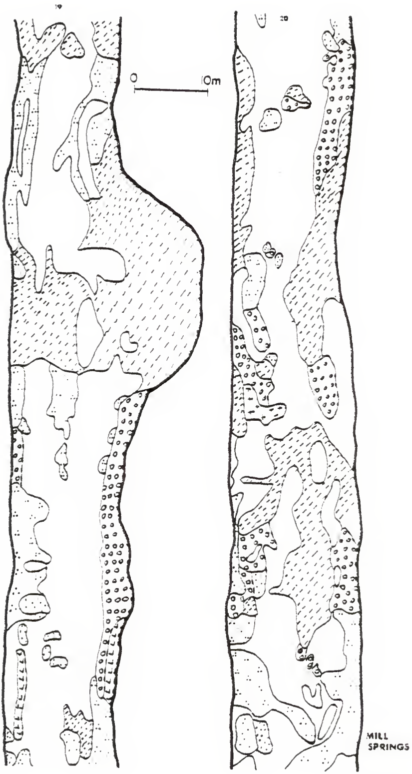
RICE MARSH

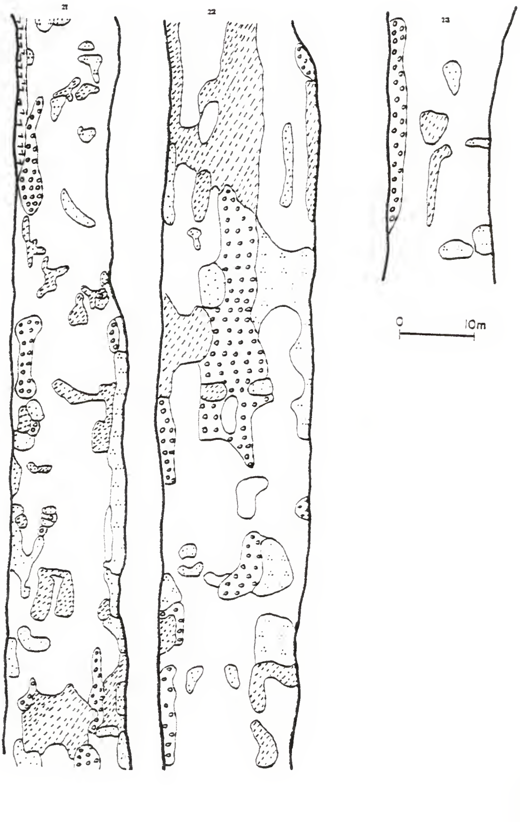



0
10m
11
12
13
DEVILS
EYE
SPRING

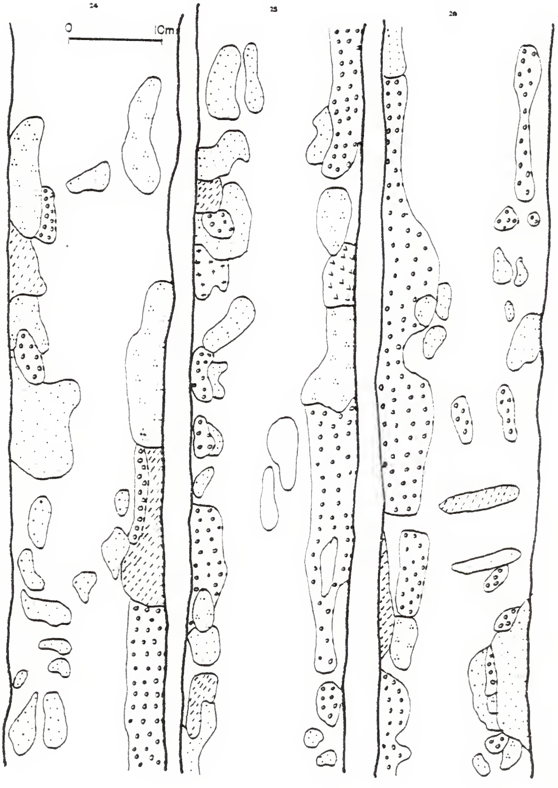

0
10m
14
15
16


0
10m

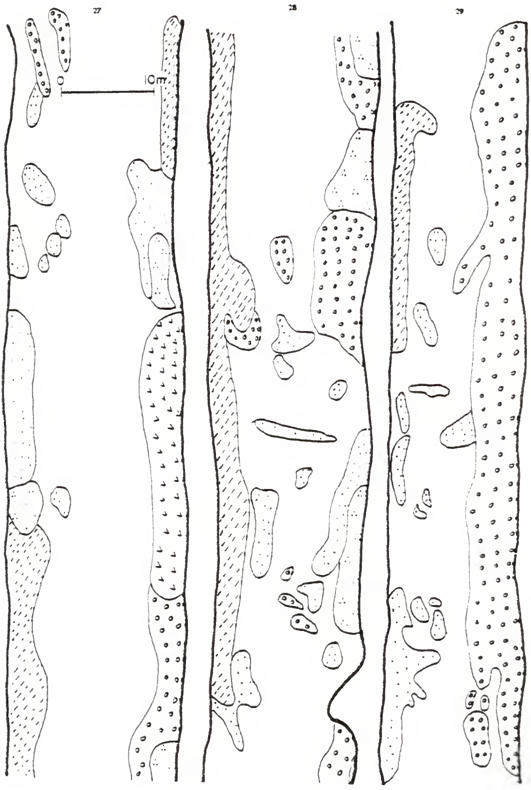

19
20
0
10m
MILL
SPRINGS


0
10m

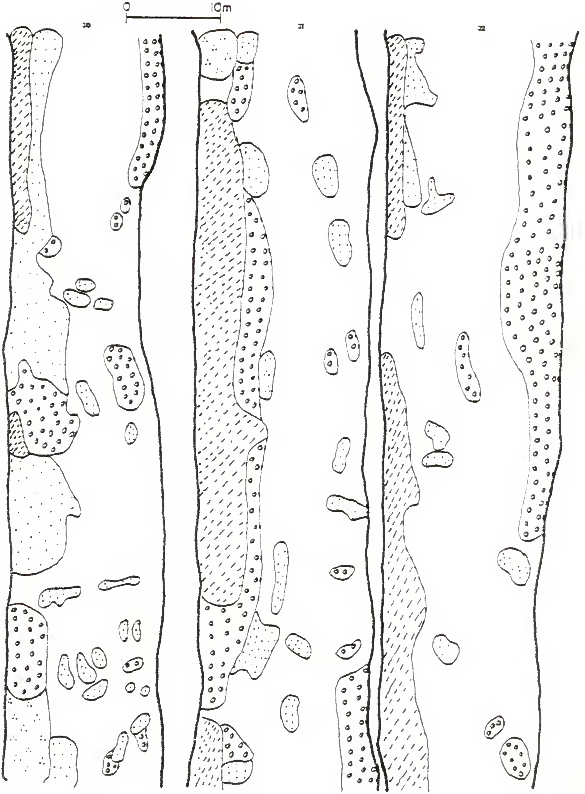
FLOODPLAIN REACH



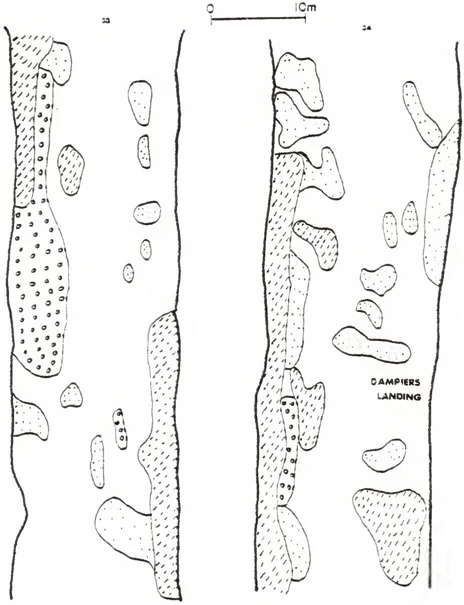
FLOODPLAIN REACH



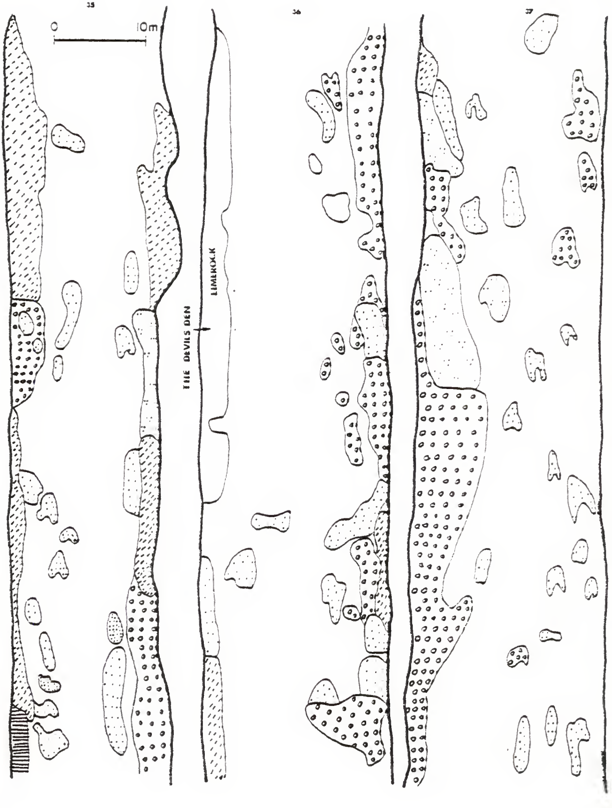
FLOODPLAIN REACH

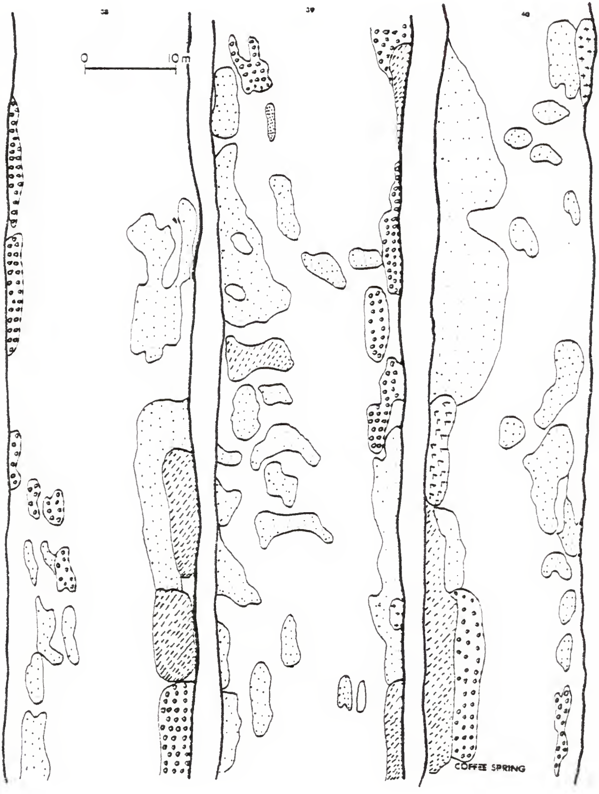


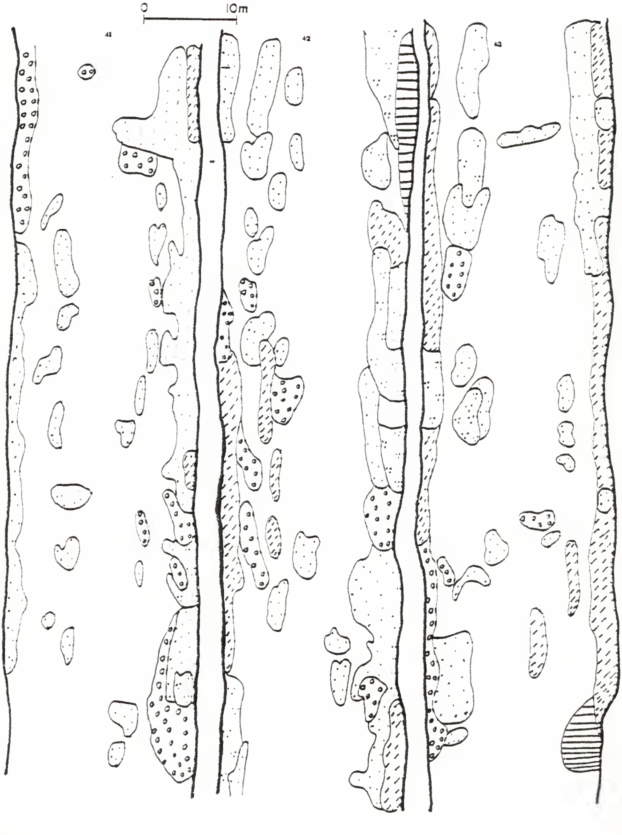
FLOODPLAIN REACH



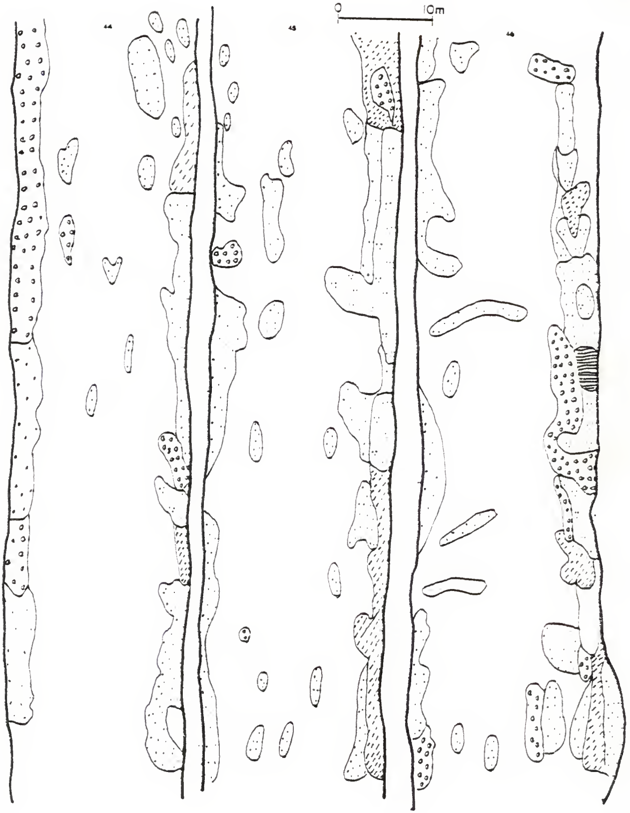
FLOODPLAIN REACH

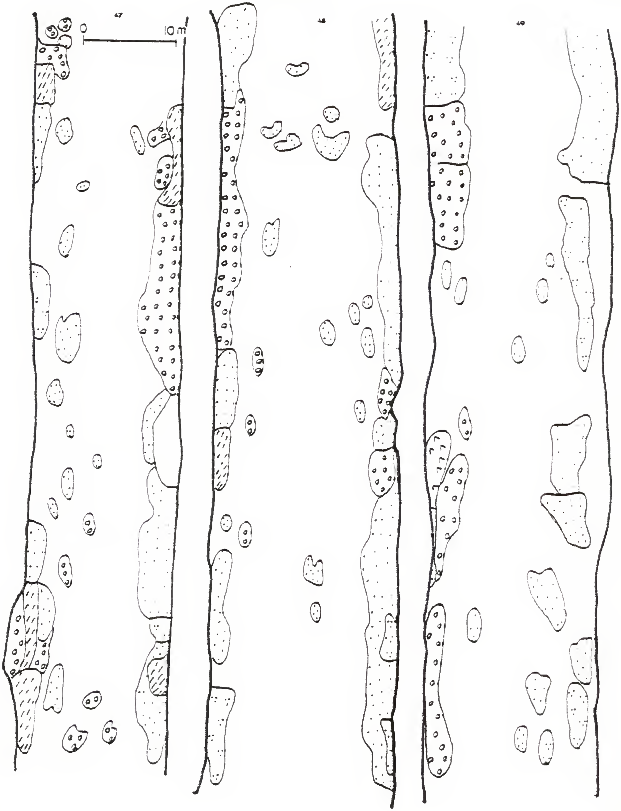


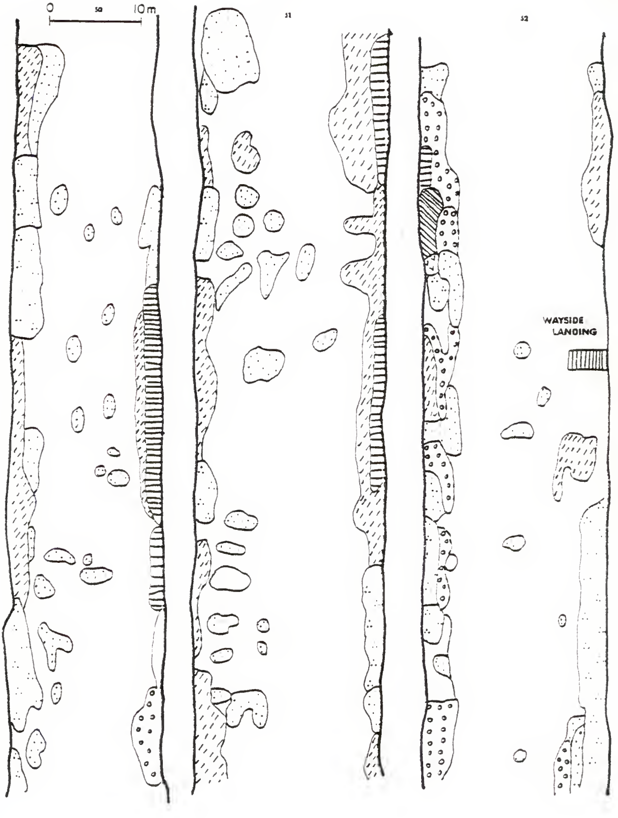

0
10 m
COFFEE SPRING


0
10m
41
42
43

FLOODPLAIN REACH




47
0
10 m
48
49


0
50
10 m
51
52
WAYSIDE
LANDING

BIOGRAPHICAL SKETCH

Charles Hill DuToit was born in Andover, Massachusetts, on June 22, 1947. He received his elementary and secondary education in the public schools of Winchester, Massachusetts, and was awarded a diploma in 1965.

Charles majored in the social sciences as an undergraduate and received a Bachelor of Arts in sociology from the University of Massachusetts in 1972. Subsequent to graduation, he developed a strong interest in the natural sciences, and, in 1973, started part-time studies as a post-graduate biology major.

In May, 1975, Charles married Marilyn Leigh Pichler of Miami, Florida. In fall, 1976, he enrolled at the University of Florida as a graduate (M.S.) student in botany.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

John Ewel, Chairman
Associate Professor of Botany

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Ariel Lugo
Associate Professor of Botany

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Frank G. Nordlie
Professor of Zoology

This thesis was submitted to the Graduate Faculty of the Department of Botany in the College of Liberal Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Master of Science.

August, 1979

Dean, Graduate School